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THE INFLUENCE OF FEAR ON THE ELECTRO-CARDIOGRAM

BY

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Received March 29, 1940

While investigating the effect of an anæsthetic on the cardiac action, we chanced on the observation that fear of an impending operation produced remarkable changes in the electrocardiogram of many persons with normal hearts. We therefore proceeded to a systematic investigation in a larger number. Having reported some of these results (Mainzer and Krause, 1939), we are now adding further material, and trying to discuss the cardiographic and clinical significance of the findings.

The circulatory response of the organism, whether normal or pathological, to various psychic stimuli is a wide field of research that has been exhaustively investigated; and the influence of a psychic emotion, such as fear, on the cardiographic tracing forms only a small part of it. Nevertheless, there is such a striking parallelism between our electrocardiograms and the tracings obtained in coronary insufficiency or in myocardial damage that a discussion seems justified.

The electrocardiogram as induced by psychic emotion has been investigated by psychologists (Astruck, 1923 ; Landis and Slight, 1929 ; Weinberg, 1923). The results, which are mostly reported in the archives of psychology or psychiatry —including the paper of Blatz (1925), who is the only one to have studied the influence of fear on the electrocardiogram—are unfortunately not at our disposal. Bier (1930) found high P, R, and T waves after pleasant excitement in some of his experiments. The majority of workers used hypnosis to provoke emotional excitement.

Boas and Goldschmidt (1930), recording the pulse rate previous to and during surgical operations with Boas' cardiotachometer, found it increased in frequency just before operation and instantly slowed down on the induction of general anæsthesia.

METHOD OF INVESTIGATION

The following procedure was taken in our examinations. In patients of the surgical or gynæcological departments of our hospital we recorded electrocardiograms : (1) one day before operation, the patient knowing nothing of the

impending operation ; (2) on the operating table just before the induction of general anæsthesia ; (3) while under anæsthesia ; and (4) on the day after operation or later, using an amplifier-electrocardiograph. The patients were recumbent, lying flat on their backs, and no drugs were given previous to the taking of the cardiogram. None of them was suffering from valvular disease of any kind or from any clinical symptom of congestive failure. We did not, however, exclude those patients who suffered from coronary sclerosis or arteriosclerotic muscular lesions. We recorded the tracings in the three classical leads. The standard gauge of amplitude was 1mV.=1·0 mm. The præcordial leads are not suitable for this kind of examination, since even a small displacement of the electrode placed near the heart in a second record may cause considerable modification of the tracing.

Results

We made observations upon 58 persons, but the records of 5 of them could not be used for technical reasons. The findings obtained in the remaining 53 are shown in Table I.

TABLE I

Electrocardiographic Changes induced by Fear of Operation

	Before Operation				Total	
	Normal Records		Pathological Records			
	M.	F.	M.	F.	M.	F.
No electrocardiographic changes induced by fear of operation ..	10	15	1	3	11	18
Electrocardiographic changes similar to those often seen in coronary insufficiency	0	12	1	4	1	16
Electrocardiographic changes as above, with P and T becoming larger and pointed also	1	3*	0	3	1	6*

* In one of these cases the change was in the P and T waves only.

The majority were women (40 females to 13 males). Twelve of the patients showed an abnormal tracing one day previous to the operation (rest-electrocardiogram) ; they were all suffering from coronary sclerosis, with the exception of one who was undernourished qualitatively as well as quantitatively (avitaminosis) owing to obstruction of the œsophagus through cancer. In 29 of the 53, four of whom had pathological tracings in the rest-electrocardiogram, the records taken immediately before operation were more or less unchanged. The remaining 24 showed pathologically changed tracings owing to fear of the impending operation.

The changes recorded can be classified into three groups :

(*a*) Those with changes that are most frequently encountered in coronary insufficiency—the S–T interval depressed below the iso-electric level (as compared

with the rest-electrocardiogram) ; the final wave T flattened or completely disappearing or becoming inverted ; S–T and T being deformed into a concave or convex curve ; more rarely, low voltage of the ventricular complex with notching; or a large Q in lead I or III. All these changes are found in more than one single lead.

(*b*) Those with changes that are usually met with in persons with neuro-circulatory asthenia or in connection with hyperthryoidism—the P and T waves becoming sharply pointed (as compared with the rest-electrocardiogram) and also showing increased voltage.

(*c*) Those with the changes described under (*a*) and (*b*) combined.

The changes of type (*a*)—as in coronary insufficiency—were encountered most often, i.e. in 15 patients, 4 of whom had already shown a pathological type of tracing at rest. Isolated changes of type (*b*)—as in persons with neuro-circulatory asthenia—were only found once. Combination of both types were more frequently present; i.e. in 6 persons, in 3 of whom the curve had already been abnormal previous to this.

As has been observed by Boas and Goldschmidt (1930), in the majority of cases a considerable acceleration of the pulse rate usually takes place previous to operation (see Table II), which, if it is very marked, may result in the fusion of the T with the P wave of the following contraction.

TABLE II

INCREASE OF PULSE RATE INDUCED BY FEAR OF OPERATION

Increase of Pulse Rate (per minute)	Nature of Record before Operation			
	Normal	Pathological	Normal	Pathological
	Without Changes of the Electrocardiogram		With Changes of the Electrocardiogram	
0–10	17	2	5	3
11–20..	2	1	2	1
21–30..	4	1	3	1
31–40..	2	0	3	1
Over 40	0	0	3	2
Total	25	4	16	8

These changes in the tracings, attributed to fear, make their appearance in the younger as well as in the higher age groups, though this might not be expected in view of the fact that in the higher age groups a greater incidence of coronary sclerosis and a tendency towards vasoconstrictor vagal action (Gilbert, 1923) prevail. Table III demonstrates that the younger age groups take their full share in this pathological response.

TABLE III

AGE OF THE 24 PATIENTS WITH CARDIOGRAPHIC CHANGES INDUCED BY FEAR

Age (years)	Before Operation	
	With Normal Records	With Pathological Records
Up to 30	12	1
31–40	2	0
41–50	0	3
Over 50	2	4

ILLUSTRATIVE CASES AND ELECTROCARDIOGRAMS

Some typical examples of the various types of " fear tracings " follow.

Fig. 1 shows a series of tracings of type (*a*), the rest-electrocardiogram of this case being normal. They are from a woman, aged 27, who was having an operation for appendicectomy.

The records taken on the day before operation (A) showed as the only remarkable feature an M-shape of the ventricular complex and a diphasic T in

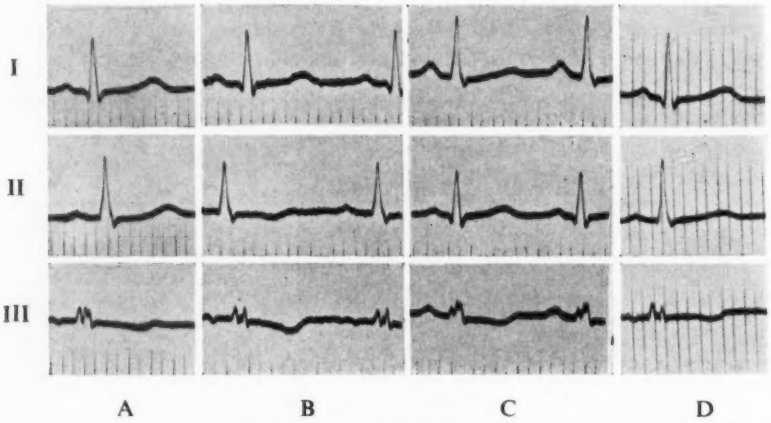

FIG. 1.—Electrocardiograms showing inversion of T_3 and partial inversion of T_2 as a result of anxiety.

(A) at rest ; (B) just before anæsthesia ; (C) during anæsthesia ; and (D) on the day after.

lead III. On the operating table (B) the S–T interval was below the iso-electric level, with a low voltage T in lead II and a negative T in lead III. As soon as general anæsthesia was induced (C) all these changes decreased in intensity. On the day after operation (D) the tracing more or less assumed the shape that had been found on the day before operation.

Fig. 2 shows how the pathological character of a record in coronary insufficiency may become accentuated. It is from a man, aged 70, who was having an operation for removal of the left stellate ganglion for gangrene of the fingers of the left hand. The rest-electrocardiogram of the day before operation (A) showed a slightly negative T_1 and an absent T_2, with S–T_2 and S–T_3 below the

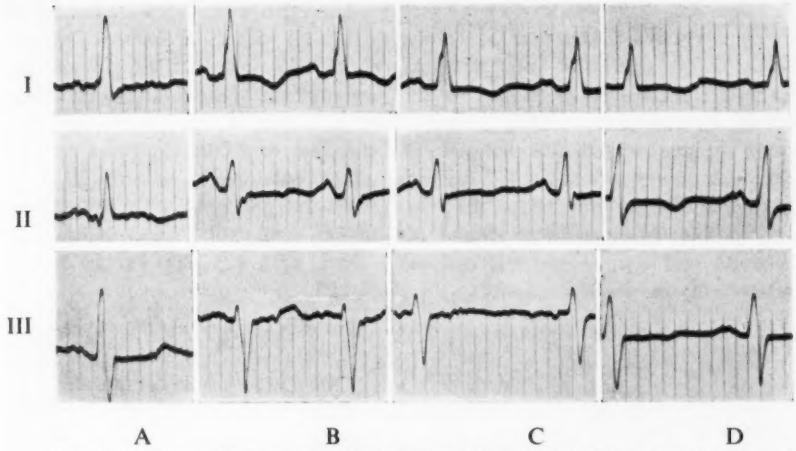

FIG. 2.—Electrocardiograms showing inversion of T_1 and partial inversion of T_2 as a result of anxiety.
(A) at rest ; (B) just before anæsthesia ; (C) during anæsthesia ; and (D) on the day after.

iso-electric level. Immediately before operation (B) the tracing changed ; the ventricular complex became pathological with left axis deviation that was not previously observed, R_2 was much lower, S (of which there was only a trace before) became distinct, and T_1 became negative and T_3 positive. Although in this case too the pathological features induced by fear disappeared to a certain extent during the anæsthesia, the tracing even on the following day was not yet quite identical with the first record.

The only record of our material that may be considered a true representative of type (*b*) is shown in Fig. 3. It is from a woman, aged 25, who was having an Alexander Adams operation for retroversion of the uterus.

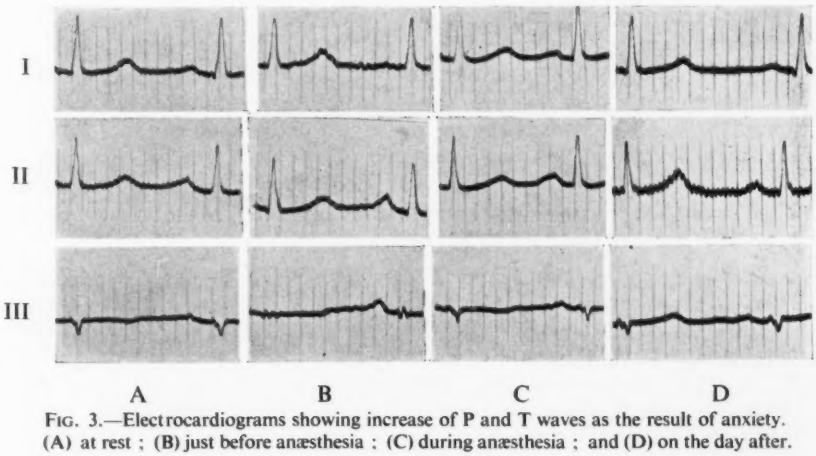

FIG. 3.—Electrocardiograms showing increase of P and T waves as the result of anxiety.
(A) at rest ; (B) just before anæsthesia ; (C) during anæsthesia ; and (D) on the day after.

The rest-electrocardiogram (A) showed no pathological features. The ventricular complex showed low voltage in lead III with T_3 negative. Immediately before operation (B) P_2 and even more P_3 increased in voltage and became more sharply pointed. At the same time the ventricular complex was lower, T_3 disappeared, and T_1 and, more markedly, T_2 became higher and more sharply pointed. In this case, too, the changes disappeared to a certain extent during anæsthesia (C). On the day after operation (D) the curve more or less assumed its original shape, save that there was a positive T wave in lead III.

Fig. 4 is characteristic of the combined type (*a*) and (*b*), so that the tracing becomes highly abnormal. It is from a man, aged 42, who was having a gastrectomy for a duodenal ulcer with obstruction of the pylorus.

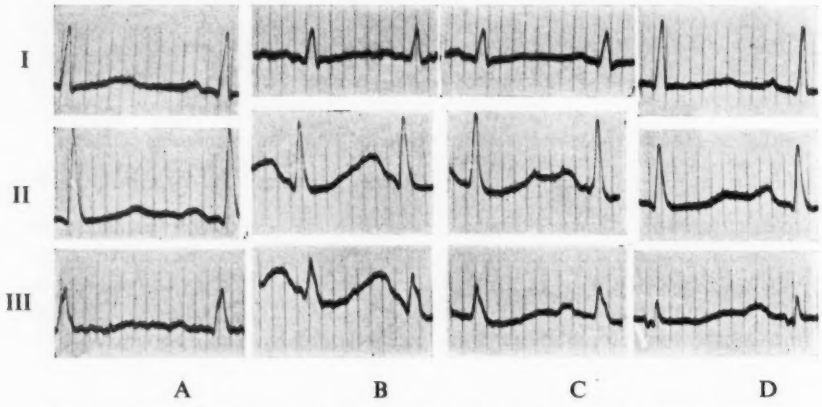

FIG. 4.—Electrocardiograms showing the earlier results combined as a result of anxiety. (A) at rest ; (B) just before anæsthesia ; (D) during anæsthesia ; and (D) on the day after.

The rest-electrocardiogram (A) of this patient may be called normal, T_1 being, however, broad and flat, and T_3 slightly inverted. The shape of this curve may have been influenced by a nutritional disorder (B-complex-avitaminosis). Immediately before the introduction of anæsthesia (B) very marked deformation existed ; in lead I, S–T and T were converted into a broad, slightly convex curve, and in leads II and III, the large T and the subsequent P formed one single large wave. During anæsthesia (C), however, the two deflections became separated to a certain degree. On the day after operation (D) the shape of the record had reverted even further, but not completely to the initial tracing; P_2 and P_3 remained high and T_3 had become negative.

In all these four cases there was an increased pulse rate before operation.

The question as to how long this " fear-reaction " of the electrocardiogram may persist has been repeatedly touched upon. In most of the remainder (17 of the 20 that showed the " fear-reaction "), a complete return of the curves to normal could be observed on the day following the operation.

The details are shown in Table IV. In 5 of these 25 patients, immediately after the induction of anæsthesia the tracing returned to its original shape. It is just as important, however, that in 3 further cases no return to the original curve took place, even after twenty-four hours.

TABLE IV

DURATION OF THE ELECTROCARDIOGRAPHIC CHANGES INDUCED BY FEAR

	Nature of Records before Operation		
	Normal	Pathological	Total
The deformation disappearing more or less during anæsthesia	1	4	5
The deformation disappearing on the day after operation	13	4	17
The deformation not disappearing completely ..	0	3	3

THE SIGNIFICANCE OF THESE FINDINGS

When taking the records on the operating table just before the induction of general anæsthesia nothing in the proceeding or in the position of the patient differed from that used when taking the other tracings, except for the different psychic condition of the patients ; hence fear of the impending operation can be assumed to be the cause of the cardiographic changes. Moreover, no drugs were given. In five of these cases the elimination of consciousness alone (through anæsthesia) was enough to make the record return to its original shape—a further proof of the emotional origin of the cardiographic changes.

This circulatory response is obviously brought about by way of the autonomic nervous system ; the idea that it may be transmitted in a humoral way only is not compatible with the immediate disappearance of the reaction observed in five of our cases, as soon as the particular psychic strain subsided.

The cardiographic changes of type (*a*) are the same as those found in men (as well as in animals) with coronary insufficiency, and these are also, in part, of a transient nature. Gross anatomical changes concerning the position and the size of the heart or affecting the cardiac walls (pericarditis, myocarditis, etc.) can be excluded from the discussion in view of the transitory nature of the cardiographic alterations. It may, therefore, be assumed that the electrocardiographic fear-reaction of type (*a*) corresponds to a reduced coronary circulation.

The problem of the vasomotor control of the coronary arteries is one of those intricate questions that can only be slightly touched upon here. If we assume (in accordance with Anrep, 1936 ; Wiggers, 1936 ; and Rein, 1931) that in the intact organism the coronary circulation is operated by the vagal tone, we may conclude that a vagal stimulus is responsible for the emotional restriction of the coronary flow. It is very tempting to conclude, on the other hand, that the increased pulse rate—as found in the reaction of type (*b*)—is produced by a sympathetic stimulus ; and that the mixed type of reaction (*c*)

may be brought about by the interaction of both factors. This interpretation remains hypothetical, since the coronary innervation has not yet been fully elucidated. Moreover, the interference of humoral factors cannot be disposed of, especially with reference to reactions of longer duration.

Their Importance for Clinical Cardiography

In clinical cardiography a certain number of records in persons with healthy hearts present a configuration of S–T and T approaching the borderline of the normal or even apparently pathological. Disturbances of internal secretion (ovarian insufficiency, deficiency diseases such as B-avitaminosis, or metabolic disorders) cannot be made responsible for these alterations of the tracing in every instance.

Many of these cases may in fact present fear-reactions, and clinically the fear may either become apparent (fear neurosis) or may remain hidden. Mainzer and Krause (1939) had the opportunity of recording three cardiograms of this kind. It would be a serious error to diagnose an organic heart disease on the grounds of such an abnormal tracing.

Sudden Death from Heart Failure Before and During Operation

Death on the operating table just before the induction of general anæsthesia (Dunbar, 1938) and deaths from cardiac failure during anæsthesia have often been reported. A transitory overdosage of the anæsthetic has been held responsible for the latter occurrence. However, a number of authors, (Hering, 1916), ascribe this event to the state of excitement provoked by the anæsthetic (chloroform) holding a vasomotor reaction (at least that taking place in the peripheral circulation) responsible for these fatal accidents (Alkan, 1930). Our observations, however, make it highly probable that these only represent the extreme cases of the otherwise ordinary fear-reaction, increased by the excitement while under the anæsthetic, and that coronary constriction must be considered the main factor.

Myocardial Damage of Neurogenic (Psychogenic) Origin

A number of clinicians have put forward the view that continuous or repeatedly recurring excitement is likely to advance organic lesions of the cardiac muscle or may even be active in producing them (Klemperer, 1929). This clinical theory of the neurogenic (psychogenic) production of muscular cardiac lesion has been supported to a certain degree by experimental work.

Manning, Hall, and Banting (1937) demonstrated that a prolonged vagal stimulation is able to produce congestion of the capillaries, extravasation of blood, and the development of hyaline foci of degeneration in the myocardium of the dog; and that the occurrence of these phenomena can be prevented by atropine. Even more marked were changes of this kind which Hall, Ettinger, and Banting (1936) were able to induce in the myocardium by administering the vagal substance, acetylcholin, to animals. In older animals this procedure will call forth multiple thromboses within the coronary area and myocardial

infarction as well as foci of hyaline or fatty degeneration with fibrous scar formation. In younger animals the arterial changes are absent and the myocardial damage is less pronounced ; in this case too atropine prevents their occurrence.

When transferring the results of these experiments to human pathology the objection might be raised that in the animal experiment the vagal stimulus and the acetylcholin dosage reached an unphysiological degree. In human pathology, however, similar observations have been made in connection with angina pectoris.

Ordinary angina pectoris is of transient nature, clinically and often electrocardiographically too. It subsides just as quickly as the psychic emotion before operation and the resultant circulatory response. Various investigators during the last decade have shown that, in spite of this transient character, the paroxysm of angina pectoris may give rise to the formation of circumscribed myocardial necrosis, which, in the course of time, may be converted into fibrous scar tissue (Gallavardin, 1932 ; Büchner, 1932 ; Holzmann, 1937). If, therefore, the heart has been subjected to a considerable number of attacks, the myocardium may be riddled with necrotic or, later, fibrous foci of microscopical size. As pointed out above, the vasomotor fear-reaction of the cardiographic type (*a*) shows a perfect analogy with that provoked by the angina pectoris paroxysm. If this is correct, the animal experiment as well as the clinical and pathological findings should lead us to envisage the probability that the emotional vagal reaction may also produce permanent anatomical lesion of the myocardium, the extent of which may depend on the degree and the frequency of the reaction.

Thus, our findings support in a certain degree the clinical hypothesis of a psychogenic origin of organic cardiac diseases.

Summary

On the operating table immediately before induction of general anæsthesia, an abnormal electrocardiographic record was found to develop in roughly two fifths of 53 cases, in comparison with the tracing of the previous day. These alterations were observed in persons with cardiac disorders, where they merely accentuated the pathological character of the cardiogram already existing, and also occurred frequently in patients with normal cardiograms. While in a number of patients the changes disappeared under the anæsthetic, or at least by the next day, they were in some cases still encountered twenty-four hours after operation.

The changes may be classified into three groups :

(*a*) S–T is depressed below the iso-electric level, and T is low, inverted, or absent altogether, S–T and T showing some deformation similar to that appearing in coronary insufficiency ;

(*b*) P and T are high and become sharply pointed, as is also found in neurocirculatory asthenia ;

(*c*) a combination of the changes quoted under (*a*) and (*b*).

Factors likely to modify the records, other than the excitement owing to fear of the impending operation, can be ruled out. In some patients the curve returns to its original shape even while they are still under the anæsthetic, thus supporting the hypothesis of a fear reaction.

In view of the analogies existing between " fear-electrocardiograms " and other types of tracings, it is assumed that the curves of type (*a*) are brought about by a reduced coronary flow, mainly to be attributed to vagal stimulation ; that sympathetic stimulation is responsible for the development of the curves of type (*b*) ; and that type (*c*) is the result of the interaction of both factors. It is improbable that only humoral factors could be active in bringing about these phenomena, in view of their rapid disappearance.

Thus in clinical cardiography a number of abnormal records that can be explained in no other way probably present genuine fear-tracings, particularly where neurotic persons are concerned.

Death from cardiac failure on the operating table immediately before the induction of general anæsthesia as well as during anæsthesia should, therefore, at least in some cases, be considered as the extreme outcome of an otherwise usual fear-reaction.

The coronary spasms of an ordinary attack of angina pectoris may give rise to the formation of microscopically recognizable necrotic foci in the myocardium. Neurogenic (vagal) lesions of the coronary arteries and myocardium have also been encountered in animal experiment. Thus myocardial damage could be induced by the vasomotor fear-reaction, as becomes apparent in the curves of type (*a*), and could be attributed to coronary constriction of vagal origin.

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CARDIOVASCULAR DISTURBANCES CAUSED BY DEFICIENCY OF VITAMIN B_1

BY

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Deficiency of vitamin B_1 causes two distinct sets of signs and symptoms, affecting either the cardiovascular system or the nervous system. In their extreme forms these conditions constitute "wet" and "dry" beri-beri. Although both systems are commonly affected, it is usual for one to dominate the clinical picture. Beri-beri is still a frequent cause of illness and death in China, Japan, the Philippine Islands, the East Indies, and Brazil; in the last few years attention has been drawn to its occurrence in the United States of America. In England gross deficiency of vitamin B_1 is rare, but mild and subclinical states are probably fairly common.

The studies of Wenckebach (1934) upon so-called "beri-beri heart" in Java and of Keefer (1930) in China have been admirably extended by Soma Weiss and his colleagues; in Boston cardiovascular disturbances, due probably to deficiency of vitamin B_1, are not uncommon; they occurred in a ratio of about 1 in 160 admissions to the medical wards, and were more frequent than congenital heart disease or subacute bacterial endocarditis (Weiss and Wilkins, 1937). Few cases have been reported in this country. One of us described two cases of cardiovascular disturbances associated with low blood vitamin B_1 to the Association of Physicians in 1938 (Sinclair, 1938), and nine cases more recently (Sinclair, 1939, *c*). Six cases with heart failure or œdema and significantly low values for vitamin B_1 diphosphate ester in the blood have also been reported (Goodhart and Sinclair, 1940). Price (1938) recorded a case of wet beri-beri associated with chronic alcoholism and a deficient diet, and Garrett (1938) a case of "polyneuritis with œdema simulating beri-beri" which he did not believe to be due to a vitamin deficiency. Yudkin (1938) described a case of wet beri-beri in an Indian living in London on a diet mainly of rice; no vitamin B_1 was found in his urine before treatment. Wood (1939) has discussed two cases; Jones and Bramwell (1939) have recently described a case of "alcoholic beri-beri" responding to treatment with vitamin B_1; and Boyd Campbell and Allison (1940) have reported a case of beri-beri (polyneuritis and changes in the electrocardiogram) combined with pellagra in Belfast.

The following three cases are reported because they were diagnosed as wet beri-beri on clinical grounds, and responded well to therapy with vitamin B_1 ; two of them gave very low values of this vitamin in the blood before treatment, but in the third this was not estimated.

Case 1. Beri-beri in a Chronic Alcoholic

A florist, aged 39, was admitted to hospital on September 9, 1936. His first symptoms, 15 months previously, were pains in the legs and numbness of the feet. Bilateral foot drop then developed, and for one year he could only walk with sticks. Six months before admission swelling of the legs and shortness of breath added to his troubles, but he continued at work, serving in his shop until August. The shortness of breath was then evident even at rest, and cough disturbed his sleep.

For 17 years he had drunk about six pints of beer or stout daily. His appetite, though never large, had begun to fail in recent weeks.

On examination he was of a ruddy complexion with slight cyanosis of the lips. Tense œdema extended half way up the thighs and round the sacrum. Orthopnœa was urgent, and the cervical veins were engorged up to the angle of the jaw in the sitting position.

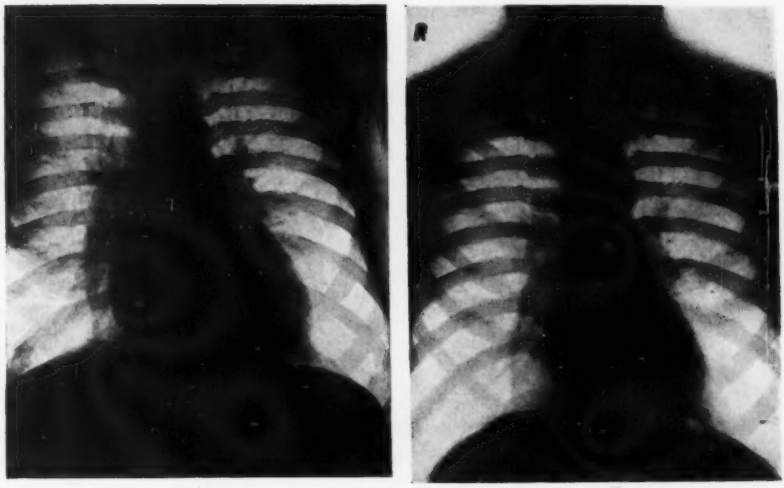
The brachial and radial arteries felt normal for his age, and no changes were visible in the retinal arteries. The blood pressure was 135/80 mm. The pulse was regular and the rate 120. The apex beat was felt three quarters of an inch external to the left nipple line. The heart sounds were tic-tac in quality, and no murmurs were heard.

The respirations were 23 per minute, and coarse rales were heard over both lung bases. The liver was tender and extended down to the umbilicus. Both grips, and flexion and extension of the elbows, were weak. There was bilateral foot-drop and tenderness of the calves. The knee and ankle jerks were absent. Sensation to cotton wool and pinprick was impaired over both forearms and legs, and also over the front of the chest and lumbar region. The urine contained no albumen or sugar.

X-ray (Fig. 1 A) showed considerable broadening of the heart shadow to the left and right, and the left contour suggested enlargement of the left ventricle. The hilar shadows were unduly stressed, as were also the vascular markings in the lung fields. Four examinations of the sputum were negative for tubercle bacilli. Wassermann and Kahn reactions were negative.

A fractional test meal showed complete achlorhydria, and the same test repeated after histamine injection showed absence of hydrochloric acid except in two samples, which were neutralized by 10 c.c. of N/10 NaOH.

Progress.—The patient was kept at rest in bed on a restricted salt and fluid intake ; his alcohol was stopped, and a diet adequate in vitamin B_1, containing two eggs per diem, was given. The dyspnœa and œdema decreased. The enlargement of the heart disappeared within a month, and still further reduction had taken place three months later (Fig. 1 B). The pulse rate, which was at first 120, declined to 80 in eight days.



A B

FIG. 1.—Case 1. Radiograms before and after treatment.

(A) September 11. The transverse diameter of the heart is much increased to the right and left ; considerable pulmonary congestion is present.

On September 22 the transverse diameter of the heart has considerably diminished (by 2·2 cm.) and the pulmonary congestion has disappeared.

(B) December 22. The transverse diameter of the heart is still further reduced, the total reduction of the transverse diameter being 3 cm.

This and the films in Fig. 2 have been taken with a standard technique, but were not teleradiograms.

The limbs, however, remained painful, tender, and weak; and as alcoholism had probably caused the peripheral neuritis, it was decided to try vitamin B_1 therapy. At that time Strauss (1935) and others in America had established the identity of alcoholic peripheral neuritis with beri-beri, and Russell (1936) in Scotland had successfully treated certain cases of peripheral neuritis with vitamin B_1. One of Russell's patients had clinical evidence of enlargement of the heart and " heart attacks." The possibility of the cardiovascular changes in this case being also due to beri-beri was then considered ; Weiss and Wilkins had published their findings in the same year (1936).

On October 10, 1936, daily injections of vitamin B_1 (500 units) were begun, and in addition marmite ʒ i, t.i.d., was given orally. In 11 days the injections were reduced to one on alternate days. By this time considerable subjective improvement had occurred : the appetite returned ; there was no dyspnœa or œdema, and the liver was only just palpable ; the pains in his limbs had disappeared and the muscles were less tender. Motor power took longer to recover, but on his discharge from hospital, in November, he no longer had foot drop and the power of his arms had recovered ; the knee and the left ankle jerks had returned, but were sluggish ; the right ankle jerk was still absent.

When seen in January both knee jerks and ankle jerks were brisk. He was walking well, and there was no tenderness of the calves.

CASE 2. BERI-BERI AND SUB-SCURVY WITH MALNUTRITION AND ACHLORHYDRIA

A metal dealer, aged 42, came to hospital on May 27, 1938. Owing to bad trade he had been on a poor diet, mainly bread and margarine, though once or twice a week he would have corned beef and a little vegetable ; he took no eggs, salads, or fruit ; he was a teetotaller. His ankles had begun to swell 18 months before, and a week before coming to hospital increasing shortness of breath was noted—even on talking. For five days he had noticed weakness and numbness of both legs. He also complained of swelling of the gums, looseness of the teeth, and intermittent attacks of epigastric pain, relieved by vomiting.

He was thin and dyspnœic, and pitting œdema extended up to the knees. The gums were spongy and bled easily. The cervical veins were slightly engorged, but there was no orthopnœa.

The pulse was 110 and regular. The radial, brachial, and retinal arteries were normal for his age, and the blood pressure was 120/80. The apex beat was in the mid-clavicular line and the heart sounds were normal. No abnormal physical signs were detected over the lungs or in the abdomen. Motor power in the legs was moderately impaired. The knee jerks were present, but the ankle jerks were difficult to elicit. The calves were somewhat wasted and tender ; objectively sensation was not impaired to cotton wool or pinprick over the lower limbs.

The heart was enlarged to the left and right, and there was evidence of pulmonary congestion in the hilar and basal regions (Fig. 2A).

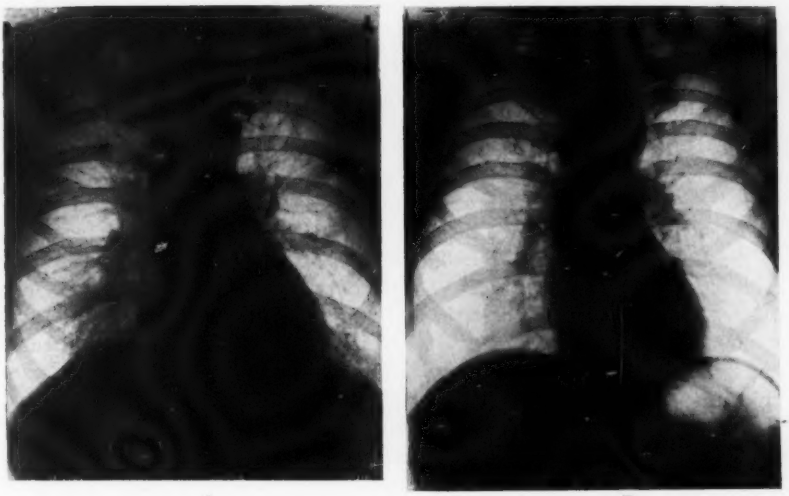
No tubercle bacilli were found in the sputum. The fractional test meal, with and without histamine, showed complete achlorhydria. The blood count showed no anæmia and no abnormality. The Wassermann reaction was negative. The specific gravity of the urine was 1022 and there was no albumin or sugar.

Progress.—The patient was kept at rest in bed on an ordinary hospital diet containing fruit juices for five days, whilst investigations were being made, including the estimation of the vitamin B_1 in the blood. As this was found to be very low (2·5 μg per 100 c.c. blood), he was then given 2 mg. of vitamin B_1 (Benerva–Roche) by intramuscular injection daily for 18 days, after which the injections were continued on alternate days for five weeks and then twice a week for another two months. During this latter period 2 mg. of aneurin were given daily in the form of Benerva tablets. Marmite ʒ i, t.i.d., was given for four weeks.

He improved steadily, the dyspnœa disappearing in one week and the œdema in a fortnight. The pulse rate fell from 110 to 80, and the transverse diameter of the heart, as seen in the radiogram (Fig. 2B), showed a considerable decrease in 17 days. The vascular congestion in the hilar and basal regions of the lungs had also disappeared.

Unfortunately an electrocardiogram was not taken until 18 days after beginning vitamin B_1 therapy. It showed an inverted T in lead III, and this had become flat a month later.

On discharge from hospital in July he was feeling well and the gums no longer bled. The weakness of his legs and the tenderness of his calves had



A B

FIG. 2.—Case 2. Radiograms before and after treatment.

(A) May 28. The transverse diameter of the heart is increased, with pulmonary congestion.

(B) June 14. Reduction of transverse diameter of heart. The evidence of pulmonary congestion has disappeared.

disappeared ; the ankle jerks, however, remained sluggish. Vitamin therapy was continued.

CASE 3. BERI-BERI AND CIRRHOSIS OF THE LIVER, IN A CHRONIC ALCOHOLIC

A publican, aged 35, was first seen on March 31, 1939. For six years he had been short of breath and had been forced to give up playing games. For a year he had been tremulous and for two weeks he had complained of pains in his legs and swelling of the ankles.

His appetite had always been small and in recent weeks had deteriorated. Morning cough and vomiting had troubled him for 18 months, and for 6 months he had suffered from recurring epistaxis. He took no breakfast. He had been in the habit of drinking 10 pints of beer and 2 or 3 ounces of whiskey, and of smoking 20 cigarettes per day. Apart from this there was nothing significant in his past history.

On examination, he was stout, and both ankles pitted on pressure. His eyes were prominent, but he asserted that they had been so ever since he could remember. There was no associated enlargement of the thyroid gland, but there was some tremor of the hands. His basal metabolic rate was later found to be +16 per cent. The exertion of getting undressed caused him to become short of breath, and the veins of the neck in the sitting position were distended up to the angle of the jaw. The pulse rate was 115 and the rhythm was regular. His arteries appeared normal for his age. The blood pressure was 130/100 mm. The apex beat could not be felt, but on percussion there was no evidence of

enlargement of the heart. A soft systolic murmur was heard over the base of the heart.

No adventitious sounds were heard over the lungs. The abdomen was prominent, and the rounded lower border of the liver could be felt five finger-breadths below the costal margin ; the surface felt rough and firm in consistency. The calves were tender, the left knee jerk was more sluggish than the right. The ankle jerks were absent. Sensation to cotton wool and pinprick was diminished on the medial side of both legs and ankles.

A teleradiogram showed a high position of the diaphragm. The heart was in the horizontal position, but did not appear to be enlarged. There was evidence of pulmonary vascular engorgement. The specific gravity of the urine was 1020 and there was no sugar and no albumin.

Pending further investigations, he was advised to continue with the same diet and intake of alcohol, and he was admitted to the West London Hospital on April 4. The vitamin B_1 content of the blood was found to be very low (1·5 μg. per 100 c.c.).

Estimation of ascorbic acid in urine : volume 75 c.c. ; 2·8 mg. per 100 c.c. ; total acid 2·1 mg.

A fractional test meal showed absence of free hydrochloric acid until the last two specimens, taken at 90 and 120 minutes, the highest reading being equivalent to 25 c.c. N/10 NaOH.

Progress.—His intake of alcohol was then stopped. Marmite ʒ i, t.i.d., was given by mouth, and also injections of 1000 units of vitamin B_1 (Benerva) were given on alternate days, and eleven days later daily.

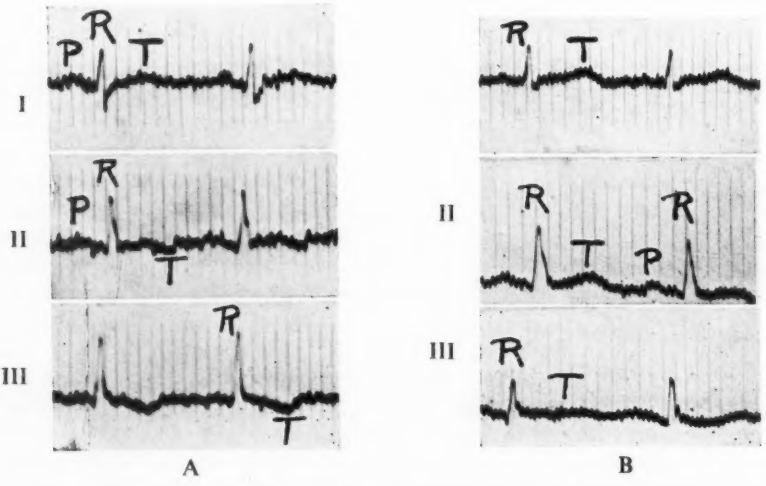


FIG. 3.—Case 3. Electrocardiograms. Time intervals 0.05 sec. Standard calibration.
(A) April 14. Sinus tachycardia, rate 100. T_2 and T_3 are negative.
(B) May 25. T_2 is now positive. T_3 is flat. T_1 is higher voltage. The tendency to right axis deviation has disappeared (see page 237).

The œdema and engorgement of the cervical veins disappeared at the end of two weeks. The pulse rate remained raised, averaging about 98. The liver decreased in size, and its lower border could only be felt three finger-breadths below the costal margin, two weeks after his admission; the size then remained unaltered, and the firmness of the organ gave the impression of cirrhosis. The pains in the legs and the hypoalgesia took about a month to disappear. On discharge from hospital in May the knee jerks were rather more brisk, but the ankle jerks remained absent. The vitamin B_1 content of the blood had risen to the normal figure of 8·5 μg. per 100 c.c.

A cardiogram taken on March 31 showed an inverted T in lead III and another on April 14 (Fig. 3A) showed a tendency to right axis deviation, with a negative T wave in leads II and III. Another taken on May 2 showed that the axis deviation had disappeared ; T in lead II was now flat, but T in lead III remained negative. On May 25, T in lead II had become positive, whilst T in lead III had become flat (Fig. 3B).

X-ray repeated on May 19 showed disappearance of the pulmonary vascular congestion ; the transverse diameter of the heart was almost unaltered, but the diaphragm was lower.

Discussion

Certain features are common to these three cases. All complained of dyspnœa and of swelling of the legs ; all had mild neuritis in the legs with tender calf muscles ; all had tachycardia and achlorhydria (or marked hypochlorhydria). Two gave a history of chronic alcoholism and had enlarged livers ; two had enlarged hearts with venous congestion but without albuminuria. hypertension, arteriosclerosis, signs of syphilis, or a history of rheumatic fever, Vitamin B_1 was estimated in the blood of two and found to be very low in amount ; all three improved after therapy with vitamin B_1.

It is customary, following Aalsmeer and Wenckebach (1929), to describe three forms of cardiac change due to deficiency of vitamin B_1 : first, a mild form occurring in ambulatory patients and accompanied by dyspnœa, palpitation, tachycardia, and slight dilatation of the right side of the heart ; secondly, a moderately severe form accompanied by œdema, mild polyneuritis, and enlarged heart and liver and spleen ; thirdly, an acute pernicious form (*shôshin*) accompanied by sudden congestive failure, præcordial distress localized to the sternum, extreme dyspnœa, and a greatly dilated heart. While the term " beriberi heart " is ascribed to any of these three forms, deficiency of vitamin B_1 can cause either neuritis without any cardiovascular disturbance or œdema without any obvious disturbance of the heart. We are not here concerned with the ætiology of famine œdema, which is probably usually due to dietary deficiency of protein. Schittenhelm and Schlecht (1919), in an outbreak in a German labour corps, attributed the œdema to the low protein and high salt content of the diet, and failed to cure it with vitamin B. On the other hand, Jansen (1920) found that the protein intake was not abnormally low in another series of cases in Germany. Whereas famine œdema is typically accompanied by a decrease in the plasma albumin and bradycardia or no cardiac disturbance

in wet beri-beri the plasma albumin is usually normal and cardiac disturbances (including tachycardia) are very frequent. The three cases described here belong to the moderately severe type of cardiac disturbance, although in one there was no evidence of cardiac enlargement.

The diagnosis in these cases rests upon four features : the clinical characteristics, the dietetic evidence of deficiency of vitamin B_1, the response to therapy, and the estimation of the vitamin in the blood.

Clinical Characteristics

The commonest cardiac symptoms of deficiency of vitamin B_1 are dyspnœa on exertion, palpitation, and tachycardia. Œdema, gallop or " tic-tac " rhythm of the heart, and " pistol shots " heard over the peripheral arteries are common. The last sign, like the decreased circulation time, is due to the widespread peripheral arteriolar dilatation and is only found associated with congestive heart failure in deficiency of vitamin B_1, in Graves' disease, and in fevers. The presence of most of these features in our three cases and the absence of evidence of other forms of organic heart disease suggest the diagnosis.

Following Wenckebach and Aalsmeer, whose cases were observed in the Orient, there has been a tendency to speak of right-sided failure. In the United States and in England there has been no uniformity of the clinical picture. The failure may be peripheral, or if central is often right- and left-sided ; the pulmonary vascular congestion in Cases 1 and 2 (Figs. 1 and 2) demonstrates the left ventricular stress.

The heart may be normal in size or much enlarged. Diuresis, reduction in the tachycardia, and often a hyperactive carotid sinus reflex are early signs of improvement. The rapid reduction in the transverse diameter of the heart is well seen in Figs. 1–2, and is comparable to that which occurs in the myxœdema heart when it is responding to thyroid medication. The peripheral neuritis responds less dramatically to vitamin B_1 therapy ; subjective improvement occurs early, but the signs usually take many weeks to disappear.

Electrocardiographic Changes.—Aalsmeer and Wenckebach (1928) and Wenckebach (1934) noted shortening of the P–R interval (0·12 sec. or less) in inhabitants of Java suffering from beri-beri. Other observers, notably Keefer (1930) in China and Weiss and Wilkins (1937) in the United States, have analysed series of cardiograms in beri-beri subjects. Feil (1936) reported on 38 cases of pellagra, but noted that the cardiographic changes were similar to those occurring in beri-beri ; possibly due to associated beri-beri. The chief abnormalities were sinus tachycardia, flattening or negativity of the T waves, prolongaton of the Q–T interval (electrical systole), low voltage QRS waves, ventricular or auricular extrasystoles, and changes in the electrical axis either to the right or left. Mainzer and Krause (1940) also reported on 23 pellagrins, in about three fifths of whom the cardiograms were abnormal ; although the changes were similar to those in beri-beri, they emphasized the return to normal in some cases subsequent to nicotinic acid treatment : there was, however, no mention of the vitamin B_1 content of the hospital diet.

Electrocardiograms were not taken in Cases 1 and 2 until four and three weeks after admission to hospital, and by this time no striking changes were present. Case 3 showed sinus tachycardia, transient tendency to right axis deviation, and negative T waves in leads II and III.

Dustin *et al.* (1939) have called attention to the increasing abnormality of the cardiograms in some cases during the first week or two of treatment. Case 3 showed this interesting sequence of events ; in the first cardiogram, taken on March 31 (not reproduced here), there were no T wave changes or axis deviation, although subsequent curves showed them (Fig. 3).

Dietetic Evidence. The Cause of Deficiency of Vitamin B_1

This has been discussed at length elsewhere (Sinclair, 1939, *a*). The requirement of the vitamin varies directly with the metabolism of the body and the ingestion of carbohydrate (or alcohol) (Cowgill, 1934) ; for this reason inanition alone does not produce deficiency. Deficiency is therefore commonest in young male adults ; particularly those who ingest large amounts or carbohydrate or of alcohol. These three patients were males aged between 35 and 42 years ; two of them gave a history of chronic alcoholism, and the diet of the third consisted mainly of bread and margarine ; all three lived on diets that were deficient in vitamin B_1. If severe neuritis limits the patient's activity, cardiac disturbances are less likely : in two of the cases the neuritis was slight, and the third was at work although he could only walk with the aid of sticks. Deficiency of vitamin B_1 tends to occur in those with gastric achlorhydria because the vitamin is easily destroyed in an alkaline medium (there is no evidence that the deficiency causes achlorhydria) : all these three had achlorhydria or marked hypochlorhydria. Further, there is evidence that liver damage impairs the utilization of vitamin B_1 because the liver is the main site of phosphorylation of the vitamin : two of these patients had enlarged livers. These factors provided adequate causes for a deficiency of vitamin B_1.

Response to Therapy

All three cases responded convincingly to therapy with vitamin B_1. It is obvious that the effect of therapy was not controlled : the patients were rested in bed and given an adequate diet without alcohol and containing marmite. Case 1, however, made much quicker progress to full recovery as soon as vitamin B_1 was administered parenterally (and marmite orally) ; Case 2 was kept on a hospital diet for five days before the vitamin was administered parenterally. The importance of parenteral administration of the vitamin, particularly in cases with achlorhydria, was shown by the case published by Laurent and Sinclair (1938), in which large amounts of the vitamin by mouth failed to cure the neuritis or raise the blood vitamin to normal. There can be little doubt that in the three cases described above full removal of the cardiac and neuritic symptoms was due to therapy with vitamin B_1. Since vitamin deficiencies are almost always multiple, controlled therapy is seldom justified, and any associated deficiency state such as pellagra, scurvy, or anæmia should receive appropriate treatment.

Vitamin B_1 in the Blood

In two of the cases the amount of vitamin B_1 in the blood was estimated by the modification of Meiklejohn's method recently described (Sinclair, 1939, *b*) ; a value of 4·5 μg. per 100 c.c. or less is significantly low. Very low values (1·5 and 2·5 μg. per 100 c.c.) were found in the two cases before treatment, and a normal value (8·5 μg.) was found in one case after treatment. There is a direct correlation between the amount of vitamin B_1 and the red cell count in the blood (Goodhart and Sinclair, 1940), but in the cases described in this paper the cell count was within normal limits. There is no doubt, therefore, that these two patients were grossly deficient in vitamin B_1. This fact, combined with the evidence presented above, strongly suggests that the cardiovascular disturbances in these three patients were caused by deficiency of vitamin B_1.

Summary

1. Three cases of cardiovascular disturbances caused by deficiency of vitamin B_1, all living in Greater London, have been reported.

2. In two the diagnosis was confirmed by finding a very low amount of vitamin B_1 in the blood ; in the third no vitamin estimation was done.

3. Two of the patients were chronic alcoholics, and in one of these cirrhosis of the liver was present. The third lived on a very poor diet with a relatively high carbohydrate content. All three suffered from peripheral neuritis.

4. Achlorhydria or hypochlorhydria was present in all the cases.

5. The diagnosis, the reaction to treatment, the influence of diet and alcohol, and other associated factors have been discussed.

We are indebted for pathological investigations, apart from the vitamin B_1 estimations, to Dr. H. Bonnell for Cases 1 and 2, to Dr. R. G. L. Waller for Case 3, and to Dr. H. E. Archer for the basal metabolic rate and ascorbic acid estimation in Case 3. Thanks are also due to Dr. J. R. Wylie for X-rays in Cases 1 and 2.

One of us (G. K.) is indebted to the Medical Research Council for a grant for expenses.

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A CASE OF BERI-BERI HEART

BY

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Received May 27, 1940

Reports of cases of heart failure due to vitamin B_1 deficiency in this country are still scanty enough to justify the publication of a single case. This one was made more interesting by being due, apparently, to a pure dietary deficiency, unconditioned by alcoholism or gastro-intestinal disease.

History of Patient

An unemployed bachelor, aged 55, was admitted on December 5, 1939, under the care of Dr. F. J. Nattrass, complaining of widespread œdema. He stated that about three weeks previously his legs and arms had begun to swell. He could not go to bed, as he lived alone, and he went about with the swelling rapidly increasing. About a week after the onset of the œdema he noticed that he was breathless on exertion for the first time. His previous illnesses consisted of a war wound in the left leg, an attack of hæmaturia in 1915, and a winter cough for the past twenty years. He had been out of work since July 1939 and his total weekly income was said to be 17 shillings, out of which he paid 8 shillings rent. He did his own catering and cooking. Details of his diet will be given below.

On admission he had severe œdema involving the legs, external genitals, and arms; there was considerable ascites. There was no respiratory distress at rest. The pulse was regular, 94 per minute, and the blood pressure was 140/85 mm.

The chest was emphysematous and the size of the heart could not be ascertained. There were no abnormal heart sounds. There was dullness towards both lung bases, but this may have been due to œdema of the back. There were no adventitious breath sounds. The liver was not palpably enlarged or tender. The retinal vessels appeared normal. All the deep reflexes were active and there was no sensory loss. The skin was not pigmented. The urine was acid with a specific gravity of 1018 and contained no albumin or sugar.

The possibility of vitamin B_1 deficiency was considered at the outset, in view of the clinical picture of widespread œdema without any satisfactory evidence of cardiac or renal disease, and the fact that the patient was living under conditions that would be likely to produce avitaminosis.

Treatment and course

On admission he received 2 c.c. of salyrgan intramuscularly, but no diuresis ensued. On the fourth day a test dose of 2 mg. of vitamin B_1 in the form of " betaxan " was given intramuscularly. The effect on the urinary output will be seen in Fig. 1. There was no result for twenty-four hours, after which the output rose quickly to reach a maximum of 160 oz. on the fifth day after the injection. The œdema rapidly subsided and at the end of ten days he was free

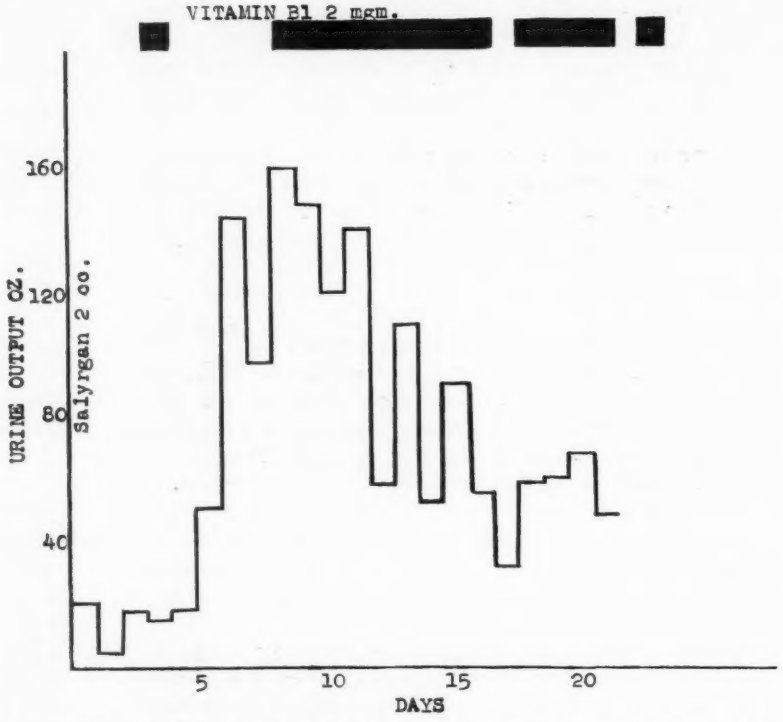


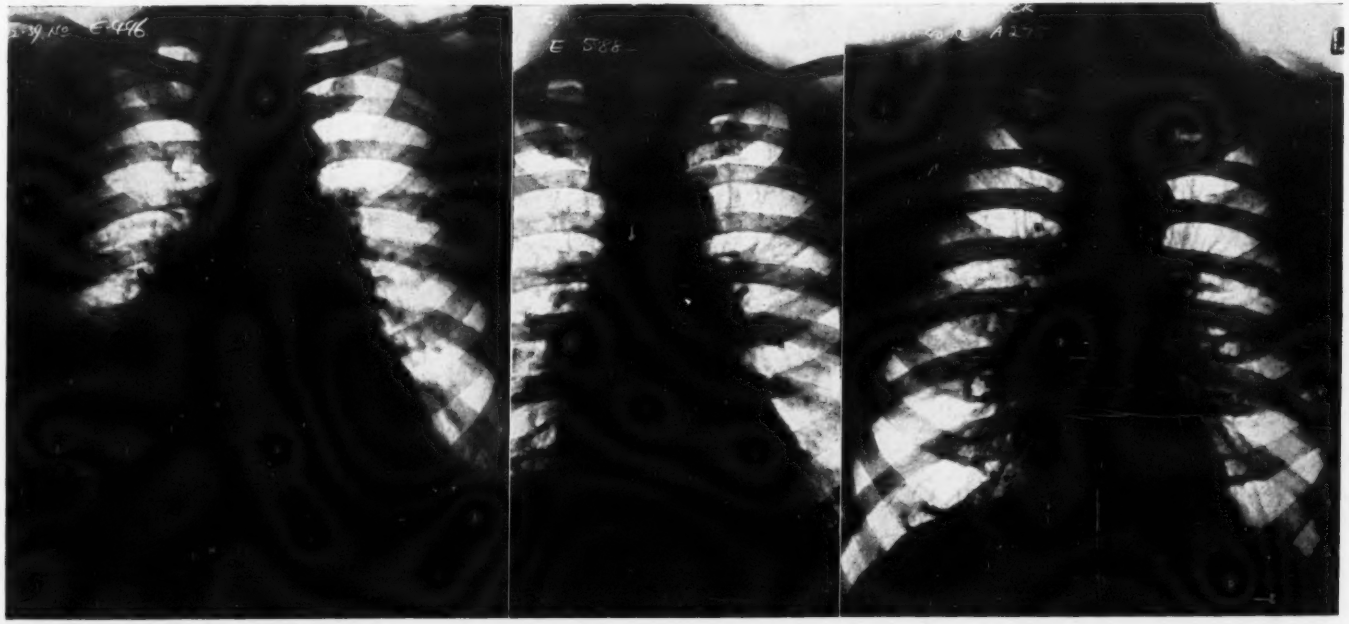
FIG. 1.—The urinary output following twenty-four hours after the initial test dose of 2 mg. of vitamin B_1.

from it and felt perfectly well. Vitamin B_1 was continued in 2 mg. doses and he received in all 32 mg. He was given ordinary hospital diet all the time and after the test period was over marmite was added.

He left hospital on February 6, 1940, free from all symptoms, and has remained well up to the present time.

Special Investigations

Radiological.—A teleradiogram (Fig. 2 A) taken on December 8 before any treatment had been given showed a considerable increase in the width of the heart



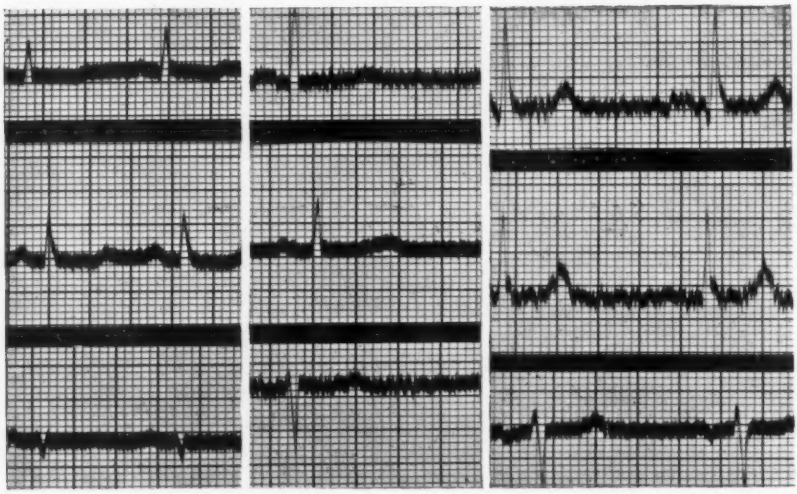
A B C

FIG. 2.—Teleradiograms before and after treatment with vitamin B_1.

(A) December 8, 1939, before treatment; note the large heart and some pulmonary hilar congestion.
(B) December 21, 1939, after 11 days' treatment; note the smaller heart and the disappearance of pulmonary congestion.
(C) January 23, 1940, after further treatment; note the continued diminution in the size of the heart and its return to normal.

shadow to right and left, with pulmonary congestion, more marked on the right side. Eleven days after treatment with vitamin B_1 had been started and at a time when improvement had set in the width of the heart shadow had decreased and pulmonary congestion was absent (Fig. 2 B). A third teleradiogram (Fig. 2 C), taken on January 23, 1940, showed a further decrease of the heart shadow to within normal limits.

Electrocardiographic.—A record taken on December 6, immediately after admission, showed a P–R interval of 0·12 sec. and rather low voltage QRS complexes ; T was flat in lead III and flattened and diphasic in leads I and II. On December 21, eleven days after treatment with vitamin B_1 had been started, the P–R interval was 0·16 sec., the voltage of the QRS complexes had increased,



A B C

FIG. 3.—Electrocardiograms before and after treatment with vitamin B_1.

(A) December 6, 1939, before treatment; the QRS waves are of low voltage, the T waves are flattened and diphasic, and the P–R interval 0·12 sec.
(B) December 21, 1939, after 11 days' treatment; the QRS voltage is higher and the P–R interval is 0·16 sec.
(C) January 20, 1940, after further treatment; the voltage of the T waves is now increased as well as of QRS.

and T was upright in all leads. On January 20, 1940, there was further elevation of T in all leads (Fig. 3).

Estimation of Vitamin B_1 in the Urine.—This investigation was carried out by Dr. W. Kelly of the Royal Victoria Infirmary, Newcastle-upon-Tyne. Estimations were made of the vitamin B_1 content of twenty-four hour specimens of urine following a test dose of 2 mg. of vitamin B_1. The results, given below, show that no significant increase in the output of the vitamin occurred.

URINARY OUTPUT OF VITAMIN B_1 FOLLOWING A TEST DOSE

Day	Urinary Volume in c.c.	Urinary Content of Vitamin B_1 in thousandths of a milligram
1–2	700	106
2–3	760	29
3–4	1540	8
4–5	3500	10
5–6	2500	13
6–7	4600	17
7–8	4160	22

Test dose of 2 mg. of vitamin B_1 given at the start.

Dietary History

The patient's circumstances forced him to try to live on 9 shillings a week after he had paid his rent. Difficult enough in normal circumstances, the rise of prices that followed the outbreak of war resulted in his already meagre diet dwindling progressively. His diet for the three months before admission is given below. It will be seen that the weekly intake of vitamin B_1 (819 international units) is far below the amount that is considered to be a minimal necessity. We are indebted to Dr. Margaret D. Wright, of the research staff of Vitamins, Hammersmith, for her trouble in estimating the vitamin B_1 content of this diet.

Usual Daily Diet	Weekly Total (including items that were taken once or twice in the week only)	International Units of Vitamin B_1
Breakfast.		
2 rounds of white bread	Bread, $4 \times 2\frac{1}{2}d.$ loaves	254
3 cups of tea with tinned milk	2 boiled eggs	50
	8 oz. tinned milk	95
	Potatoes $10\frac{1}{2}$ oz. (twice)	90
Dinner.		
Kippers, fish cakes, black puddings, meat, or sausage with potatoes	Sausage	100 (?)
	Meat 1 lb.	230
	Beer $1\frac{1}{2}$ pints	0
		819
Tea.		
2 rounds of white bread		
3 cups of tea with tinned milk		
Supper.		
None		

Discussion

This case appears to be one of pure dietary deficiency of Vitamin B_1. There was no excessive indulgence in alcohol, as in Jones and Bramwell's recent case (1939), and although no elaborate investigations were undertaken there is no reason to suspect gastro-intestinal disease, such as Ungley (1939) and many others have mentioned as a contributory factor. Furthermore the case presented no evidence of polyneuritis or skin pigmentation, as is described by Boyd Campbell and Allison (1940), but was a case of pure heart failure.

Summary

A case of beri-beri heart is recorded.

The deficiency was apparently due solely to defective diet.

A clinical cure followed the giving of vitamin B_1.

Electrocardiographic and radiological changes were present and disappeared after vitamin B_1 had been given to the patient.

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PULMONARY STENOSIS PRODUCED BY ANEURYSM OF THE ASCENDING AORTA

BY

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Received April 24, 1940

Although aneurysm of the aorta is not itself uncommon, its location so that pulmonary stenosis and insufficiency result and so that the symptoms and signs simulate those of aneurysm of the pulmonary artery justifies a report and brief discussion.

Case Report

A negro woman, 28 years of age, was first admitted to Charity Hospital of Louisiana at New Orleans in May 1938, complaining of shortness of breath, which had been present for two weeks. A month before, an attack of what she termed " indigestion " had been followed by severe diarrhœa with considerable tenesmus and the passage of pure blood; the diarrhœa disappeared within a week and she felt fairly well for two weeks. Then she had a sudden, severe stabbing pain in the left chest, radiating to the left shoulder. She was dyspnœic and restless. The pain continued, at first with remissions, until she entered the hospital. The past history contained no relevant facts.

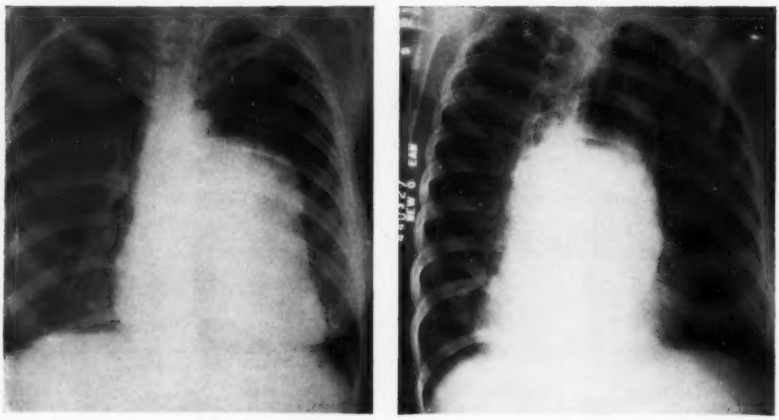
Physical examination revealed a fairly well developed and well nourished woman who appeared acutely ill and was dyspnœic even on a high back rest. The pulse rate was 90 per minute, the respiratory rate 20, and the blood pressure 95/40. The skin and mucous membranes appeared slightly pale.

The chief physical findings were confined to the chest. There was slight fullness in the anterior thoracic wall in the third interspace, pressure over which elicited some pain. Expansion was equal on both sides, and resonance and breath sounds were normal. The apex beat of the heart was best seen and felt in the fifth interspace, slightly outside the mid-clavicular line. Percussion revealed the heart to be slightly enlarged to the left. There was a systolic thrill over the præcordium, and a continuous murmur with systolic accentuation, heard most clearly over the area of the pulmonary valve but also audible over the entire præcordium, and replacing the second pulmonary sound. The arteries felt normal and the pulse, although of slightly low tension, was otherwise normal and not of the Corrigan type.

The abdomen was somewhat distended, but was otherwise normal. Pelvic examination revealed old inflammatory disease and rectal examination showed external hæmorrhoids and lymphogranulomatous obstruction an inch from the

anal opening. The extremities were normal, and the reflexes were normal and equal on both sides. The urine was normal and the blood Wassermann reaction was strongly positive.

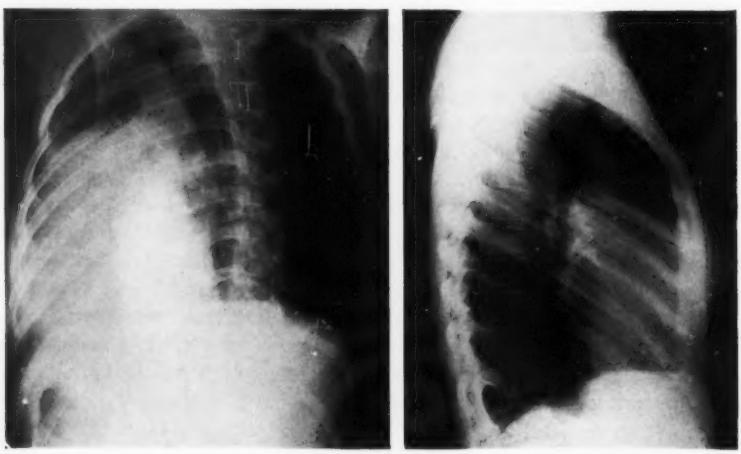
At this time, as on all subsequent admissions, the radiologist reported an aneurysm of the pulmonary artery (Figs. 1–2), the measurements of which were



A B

FIG. 1.—(A) Radiogram of chest, showing a normal aortic knob and enlargement in the region of the pulmonary conus and artery.

(B) First oblique position, showing the aneurysm of the ascending aorta.



A B

FIG. 2.—(A) Radiogram (second oblique position) showing the aneurysm of the ascending aorta.

(B) Lateral view of chest, showing the aneurysm of the ascending aorta pressing on the anterior thoracic wall.

never satisfactorily secured. The electrocardiographic report, which also was substantially the same on each admission, read as follows: very slight right axis deviation, P_1 and P_2 slightly high, P–R interval normal (0·16 sec.), Q–T slightly long (0·40 sec.), S–T slightly depressed, and T waves normal (Ashman's formula, 1939).

The patient discharged herself from hospital, but was readmitted later in the same month for treatment of her pelvic condition. She remained in a gynæcological ward for three weeks, the findings being essentially the same as those already recorded.

After a third admission in October for treatment of her rectal stricture, when she only remained in hospital five days, she was admitted for the fourth time in January 1939. She complained of the same stabbing pain in the chest, but it was now more severe. Her hands and feet had been swollen for some days.

The pulse rate was 88 per minute, the respiratory rate 18, and the blood pressure 130/78. She was dyspnœic, and the skin and mucous membranes were pale. Physical examination was essentially the same as before, except that tenderness in the præcordial area and the fullness in the third interspace were more pronounced. The continuous murmur with systolic accentuation was also more prominent. The liver was enlarged two fingers' breadth below the costal margin. There was no fluid in the abdomen, but there was a slight pitting œdema of the feet and ankles.

As during her first stay in hospital, the patient had slight daily rise of temperature to 99–99·5° F. Pain and dyspnœa continued, and symptomatic relief could be secured only by sedatives at regular intervals. She was unwilling to remain in hospital and was finally permitted to leave, unimproved.

She returned for the last time in March 1939, with all her symptoms and findings markedly exacerbated, and with clear evidence of congestive heart failure. She improved under treatment during the next two months, but developed pulmonary œdema in May and died within a few hours. Radioscopic examination shortly after she entered the hospital in March revealed the supposed aneurysm in the region of the pulmonary artery; at this time the posterior mediastinum was clear.

A post-mortem examination was made by Dr. Bjarne Pearson. Each of the pleural cavities contained 800 c.c. of straw-coloured fluid. The pericardial cavity was obliterated by fibrous adhesions, but it was fairly easy to separate the pericardium from the anterior surface of the heart.

The heart weighed 525 g. and had the following measurements: tricuspid valve, 13·0 cm.; pulmonary valve, 9·0 cm.; mitral valve, 10·0 cm.; aortic valve, 7·2 cm.; left ventricle, 2·0 cm.; right ventricle, 1·0 cm.; left auricle, 0·6 cm.; right auricle, 0·7 cm. The myocardium was firm and light red. No areas of infarction were seen. The coronary arteries showed no sclerosis and their orifices as well as their branches were normal.

The chief pathological finding was an aneurysm of the aorta, located above the junction of the right and left anterior cusps (Fig. 3). It formed a herniation that protruded into the pulmonary artery (Fig. 4), which in turn protruded into

FIG. 3.—Heart, showing the aneurysm of the ascending aorta (A) above the aortic valves (B). The aneurysm extends between the origins of the coronary arteries, which are not well visualized. C indicates the area in the wall of the aneursym from which sections were taken for microscopic study.

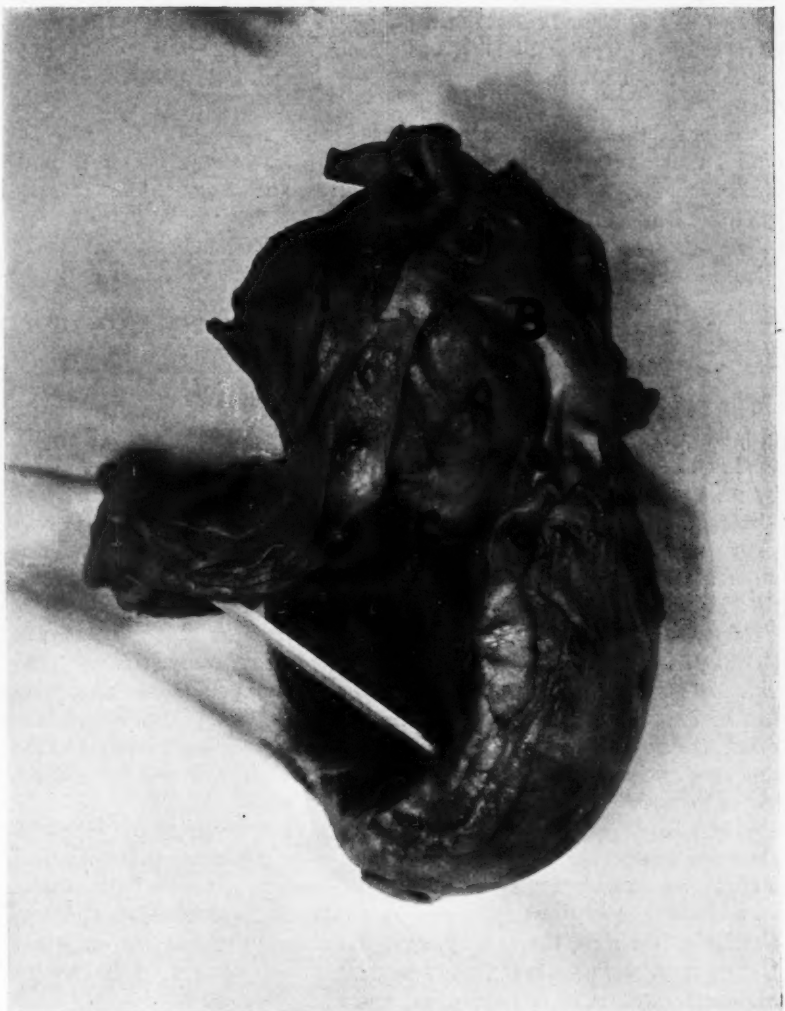


FIG. 4.—Heart, showing aneurysmal sac (A) bulging into the pulmonary artery (B) and obliterating the left posterior cusp (C), thus producing pulmonary stenosis and insufficiency. Note hypertrophy of right ventricle.

the right ventricle, the combined pressure and anatomical distortion causing stenosis of the pulmonary artery. The aneurysmal sac also distorted the right posterior cusp of the pulmonary valve so that it could not be recognized as such and appeared merely as a thin rim of tissue. Evidence of early pressure changes was seen on the internal surface of the chest overlying the aneurysm, but there was no erosion. The mouth of the aneurysm measured 2·25 by 2 cm., the depth was 5·75 cm., and the transverse and the posterior diameters were both 6·5 cm.

Except for the spleen, which weighed only 60 g., and the pelvic organs and rectum, which revealed the conditions described clinically, the other post-mortem findings were unimportant. Microscopic examination revealed syphilitic changes in the aorta.

The diagnosis was aneurysm of the aorta with pulmonary stenosis caused by herniation of the aneurysm into the pulmonary artery.

Comment

The pertinent literature is not extensive. Aneurysm of the pulmonary artery is rare. Wahl and Gard (1931) found only 70 cases on record up to 1925, including the case they themselves were reporting.

Crawford and de Veer (1932) reported an aortic aneurysm located 1 cm. above the right and left aortic valves, which pressed on the base of the pulmonary artery and conus, as well as on the interventricular septum, and thus produced a right bundle branch block. They cited the similar case reported by Rothschild *et al.* and the cases reported by Bruffalini and by Stejfa.

Delp and Maxwell (1938) reviewed the papers on rupture of aortic aneurysms into the pulmonary artery and collected 46 cases, including their own. They mentioned that Boyd had reported 18 such ruptures in 592 aortic aneurysms and Stevenson 3, and that single cases had been reported by Kappis, Peacock, Taylor, Kork, and Potter. Kampmeier (1938) found only one rupture into the pulmonary artery in 633 aortic aneurysms, and observed four aneurysms of the sinus of Valsalva in the same material.

As this paper was being prepared for press there appeared the report of Garvin and Siegel (1939) concerning three cases of cor pulmonale due to obstruction of the pulmonary artery by an aneurysm of the aorta. On the basis of their own and other observations they conclude that: if myocardial insufficiency, especially of the right heart, is evident; if radioscopy shows the aneurysm in such a position that it could press on the pulmonary artery; if the electrocardiogram reveals right axis deviation; and if all other causes of heart failure are excluded; then the diagnosis of obstruction of the pulmonary artery by pressure from an aortic aneurysm should be considered probable.

In the case here reported several clinicians were unable to agree upon the diagnosis, and aneurysm of the pulmonary artery, aneurysm of the aorta with rupture into the pulmonary artery, aneurysm of the sinus of Valsalva, and aneurysm of a patent ductus Botalli were variously suggested. The first was

considered the most probable, though the combination of an aneurysm of the pulmonary artery with a patent ductus Botalli was discussed as a possibility. The radiologists argued for an aneurysm of the pulmonary artery, because the films revealed a normal aortic knob with the main shadow overlying the region of the pulmonary artery (Figs. 1–2), and radioscopy shortly before death revealed a clear posterior mediastinum, which seemed to indicate that the aneurysm pointed forward in the region of the pulmonary artery. Wahl and Gard's views of pulmonary aneurysms are comparable with the views taken of this particular case.

Since the patient had previously been in fairly good health and had had no symptoms until her twenty-eighth year, the diagnosis of congenital heart disease as manifested by a patent ductus Botalli seemed somewhat unreasonable, particularly as the first complaint referable to the cardiovascular system was moderate dyspnœa, with stabbing pain in the præcordium. The continuous murmur heard over the chest, combined with the radiological findings, made the diagnosis of aneurysm almost a foregone conclusion. The præcordial pain as well as the extreme tenderness over the third left interspace favoured some involvement of the pulmonary artery. There was no evidence of mitral disease and the slight right axis deviation was considered due to some disease in the pulmonary artery itself. On the other hand, there was no doubt of the existence of an old syphilitic infection, as proved by repeated positive Wassermann reactions, and syphilis of the pulmonary artery is extremely rare. It was therefore felt that if the aneurysm did involve this artery, some cause other than syphilis must be responsible.

At autopsy these conflicting findings were made clear when the lesion was revealed to be an aneurysm of the aorta located immediately above the sinus of Valsalva and directed forward and slightly to the left. It pressed upon the base of the pulmonary artery and thus obliterated the posterior cusp and produced pulmonary stenosis and insufficiency.

Of the several reports on record concerning rupture of an aortic aneurysm into the pulmonary artery, the case reported by Crawford and deVeer (1932) resembles the case herewith reported so far as location is concerned. In this instance, however, rupture did not occur and the clinical picture simulated that of pulmonary aneurysm.

Summary

A case is reported in which an aneurysm of the aorta was so located as to produce pulmonary stenosis and insufficiency, and a clinical picture suggestive of aneurysm of the pulmonary artery. Previous reports are briefly reviewed, and it is pointed out that the location of the aneurysm in the reported case is very unusual, as are its ultimate effects upon the pulmonary system.

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ANEURYSMAL DILATATION OF THE PULMONARY ARTERY

BY

K. D. WILKINSON

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Aneurysmal dilatation of the pulmonary artery as a result of congenital defect is most commonly associated with a patent inter-auricular septum. This was not so in the present case, which seems to be worth record on account of its rarity.

The child in question appeared normal up to the age of ten years. The second child of healthy parents, she had bronchopneumonia at the age of six and catarrhal jaundice at nine, yet no cardiac defect was noted ; at ten years of age she was a spare child who weighed 42 lb. She was then admitted (in March 1936) to the Children's Hospital in Birmingham on account of breathlessness. This had only been noticed a short time during the winter of 1935–36, and her mother had also observed that her heart beat unusually forcibly and that her chest bulged forward and to the left side.

She was a healthy-looking girl with a fresh colour, quiet and friendly, and not excitable. The respiratory movement of the chest on the left side was limited. The heart was considerably enlarged, the apex being difficult to localize accurately, but the maximum impulse lay in the seventh left interspace, four inches from the midline. The area of cardiac pulsation was extensive, and the cardiac dulness extended up into the second left interspace in the mid-clavicular line.

The pulse was regular, 120 per minute, and of poor volume. The blood pressure was 104/64 mm.

At the apex the first sound was loud and appeared to be double, with a long systolic murmur. The second sound was loud and sharp. At the base both sounds were loud and clearly heard, and the first was followed by a long, blowing systolic murmur, maximal in the second left interspace, but audible over a wide area. The second sound was loud and there was no diastolic murmur.

During her stay in hospital she improved and the pulse rate fell to under 90. The electrocardiogram showed a low voltage in lead I, with a tall R_2 and R_3 and a P–R interval of 0·16 of a second.

She was readmitted on April 29, 1939, because she had developed a spinal curvature—which was reported to be due to an early osteochondritis of the spine. She then weighed 50 lb. and had grown a good deal. The condition of the heart was as before: the systolic murmur was audible all over the chest;

the second sound was remarkably loud everywhere; and there was no diastolic murmur. The sedimentation rate was 5, and there was no evidence of infection. Radioscopy confirmed the great enlargement of the heart and showed some dilatation of the right pulmonary artery and an enormous shadow coming from the left pulmonary root (Fig. 1). This was also well shown in a partial oblique view with the patient turned slightly to her left (Fig. 2).

FIG. 1.—The direct antero-posterior radiogram (taken on April 14, 1939) shows gross enlargement of the pulmonary artery extending up to the second left interspace. The heart appears to lie a little to the left and the shadow almost completely fills the left chest. The pulmonary root on the right shows a large shadow, probably venous.

FIG. 2.—A slightly oblique radiogram, taken on April 14, 1939, shows the pulmonary distension and the cardiac enlargement below. The left lung is seen to be clear. The child had been slightly turned to the left, with the right shoulder forwards.

There had been no attack of syncope or cyanosis and no special complaint had been made about the heart. She was in hospital for a month and was provided with a spinal support, which she wore. After her discharge she continued to attend school, and appeared to enjoy normal health. She played no games and did not do physical exercises.

On September 5, 1939, when she came in from school at tea time, she said that she was tired and sat down. As she sat forward watching her mother transplanting a small plant, she suddenly put her hand to the left side of the chest and cried out " Oh, mother, the pain ! " She fell forward and was " dead in a minute."

Post-Mortem Findings

There was definite bulging of the thorax to the left and a slight degree of kypho-scoliosis. The pericardium was tremendously distended with fluid blood, and the heart so enlarged that the left lung was considerably compressed.

There were no pleural adhesions, but the left lung root was infiltrated with blood. The pulmonary artery was very large, the diameter being three inches, and its general appearance is well shown in Fig. 3. The effusion of clotted

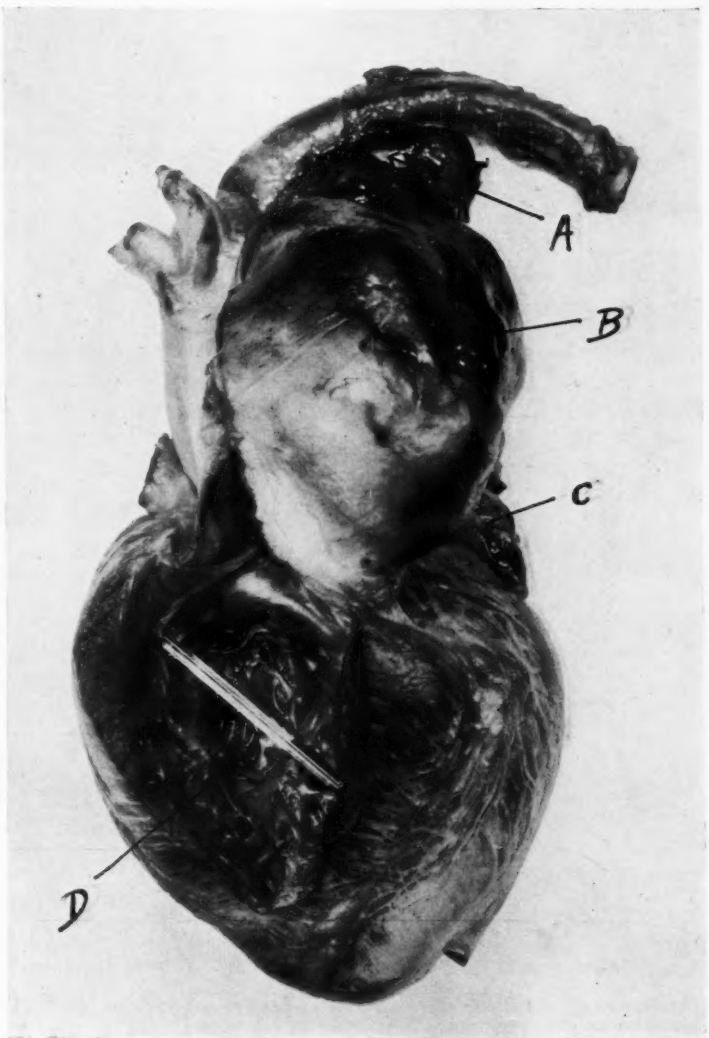

FIG. 3.—Photograph of the heart and great vessels post mortem, showing the great dilatation of the pulmonary artery.

(A) Clot of effused blood between the aorta and the aneurysm of the pulmonary artery.
(B) Effused blood in the wall of the aneurysm.
(C) Left auricle.
(D) Opened right ventricle.

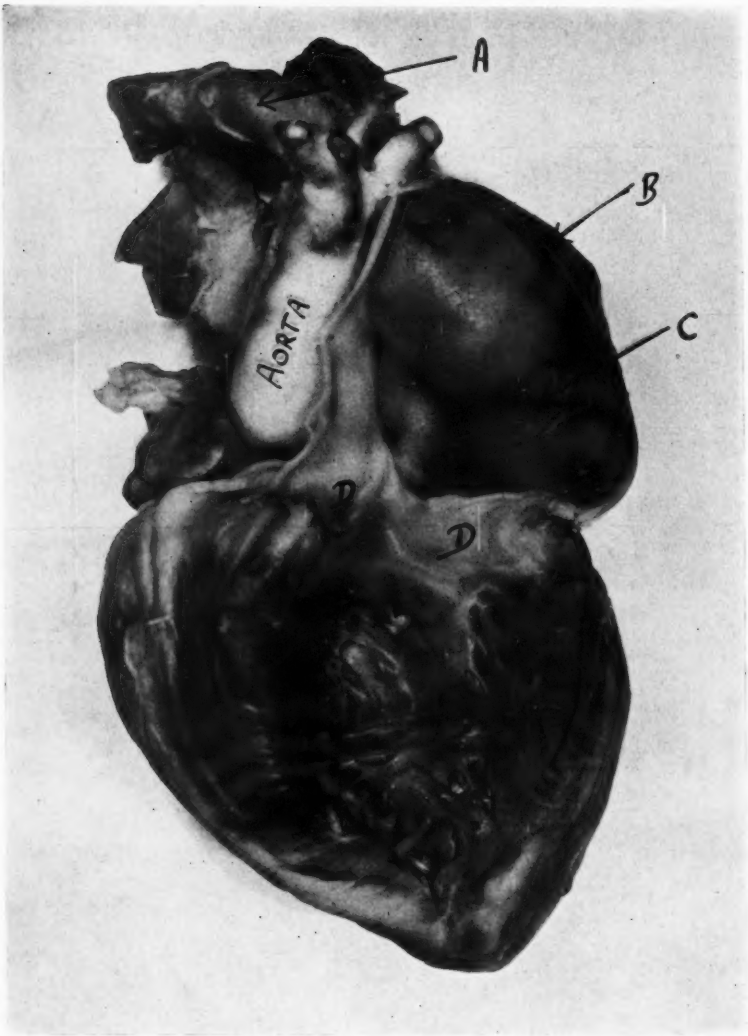

FIG. 4.—Photograph of the heart and great vessels post mortem. The right ventricle and the dilated pulmonary artery have been opened.

(A) Left pulmonary artery discoloured by effused blood.
(B) Effused blood in wall of dilated artery which has been opened.
(C) Site of rupture of the pulmonary artery.
(D) Two cusps of a bicuspid pulmonary valve.
(E) Just to the left of E is a small patency of the inter-ventricular septum.
(F) Tricuspid valve.

blood can be seen at A, between the aorta and the aneurysm of the pulmonary artery, and again at B, in the wall of the aneurysm (Fig. 3). The front of the artery and its left branch were infiltrated with blood extending into the root of the left lung.

About one inch above the valve was a linear split (Fig. 4 C), two inches in length, extending through the intimal coat and the medial coat and at one point through to the pericardium ; elsewhere the adventitial coat remained thin film like tissue-paper.

Above the split the wall of the artery was dissected between the media and adventitia well into the root of the left lung, and this is shown in Fig. 4 (A and B).

Both the ventricles were somewhat enlarged, and their walls were thickened, while immediately below the pulmonary orifice was a small inter-ventricular communication (Fig. 4 E). The aorta was possibly slightly smaller than normal for the age.

The pulmonary valve was bicuspid and very large (Fig. 4 D), the cusps being quite soft and of normal texture. The aortic, mitral, and tricuspid valves were normal.

The auricles were not noticeably abnormal and the inter-auricular septum was intact. The myocardium appeared normal.

Summary

A case is reported in which an aneurysmal dilatation of the pulmonary artery, due to a congenital defect, led to sudden death from rupture of the walls of the artery, the rupture also producing some degree of dissection of the coats of the artery.

A NOTE ON PULSATING MANUBRIAL TUMOUR

BY

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From University College Hospital

Received June 22, 1940

In the two cases that are here described pulsating tumours over the upper part of the sternum simulated pointing aneurysms,but were in reality secondary deposits from neoplasms elsewhere.

Case 1

In December 1932 a man of 48 was sent to me for an opinion. He said that 15 months previously, while engaged in work as a house demolisher, he fell down two stories through a shaft. He broke an arm, a leg, and ribs, and had been unable to work since the accident. His chief complaints were of shortness of breath and of pain over the region of the upper part of the sternum, radiating to the shoulder and down the arms to the elbows, though unrelated to exercise. He came diagnosed as a case of aneurysm of the aorta, and a second opinion was required because he was claiming compensation for injury arising out of his employment. On stripping him I found an obvious swelling over the manubrium sterni. It extended from the top of the manubrium to the upper border of the first rib, and a little beyond the sides of the sternum laterally. The rounded lump projected about 1·5 cm. ; the skin over it was not discoloured ; there was visible and palpable pulsation, the tumour expanding with each heart beat. A long but inconspicuous systolic murmur was audible over the tumour. The Wassermann reaction was positive. The pulses were equal, and there were no pressure symptoms or signs. At first there seemed little reason to question the diagnosis, but closer examination gave rise to increasing doubt. The first point to arouse suspicion was the shape of the tumour itself ; in the middle line the mass was hemispherical, but in the first right interspace an inconspicuous flattened tongue projected from it for 2 cm., also pulsating. Moreover, a finger could be carried down behind the sternum a little way without meeting resistance. The second point was that the pulsation of the tumour, when compared with that of the carotid artery, seemed softer and less abrupt than was to be expected, and very slightly but distinctly delayed. He gave incidentally a history of passing a small quantity of blood in the urine on two occasions many months before. The urine was normal, but the blood urea was a little raised. The right kidney was palpable and seemed enlarged. I refused to confirm the diagnosis of aneurysm, believing the tumour to be a new growth.

I was asked to re-examine the man in March 1934, 15 months later, from the same point of view as previously. His symptoms were unchanged ; so were the signs, except that the manubrial tumour had increased perceptibly in size, and he was thinner. On this occasion, however, X-ray examination detected what was not present before, namely, an abnormal shadow above the level of the knob of the aorta, extending also above the level of the manubrium, and a clear picture of a secondary deposit in the upper part of the shaft of the left humerus.

The diagnosis was now unmistakably hypernephroma with secondary deposits.

The interest of the case lay, of course, in its original resemblance to pointing aneurysm, and most noteworthy were the relative softness of the pulsation and the slight but perceptible delay in its rise, a delay confirmed at the time by records shown in the figure below.

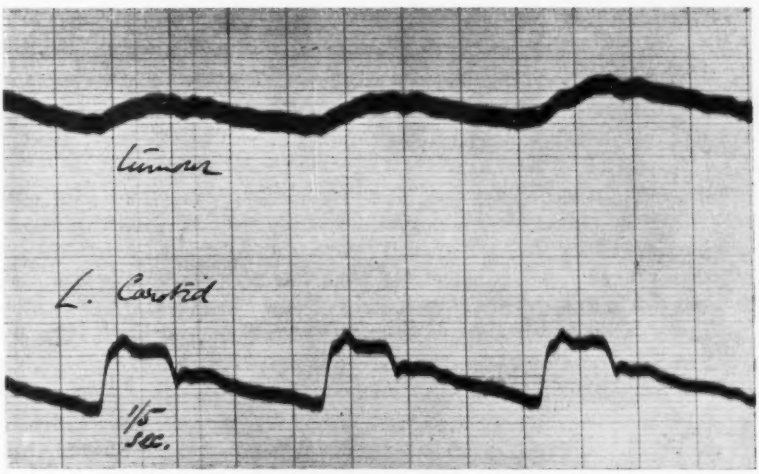

FIG. 1.—The upper curve, taken from over the tumour in the manubrium sterni, indicates that pulsation there was slightly later than the pulsation of the carotid pulse.

Case 2

In June 1939 a man of 58 years was admitted under my care complaining of hiccough and vomiting of six weeks' duration, the passage of a little blood in the urine for three weeks, and a lump that had developed recently over the upper part of the chest.

He had full signs of tabes dorsalis and a tongue presenting advanced chronic superficial glossitis ; the Wassermann reaction was positive.

A tumour projected over the right sterno-clavicular joint and below it. It was hemispherical, and about 5 cm. in diameter, and pulsated quite distinctly. The heart was much enlarged, and over the tumour a loud systolic murmur was audible. The second right space was dull to percussion, and a tracheal tug was

detected ; the pulses and pupils were equal, and there were no pressure signs. X-ray examination showed a greatly dilated aorta. The blood pressure was 220 systolic, 140 diastolic; the blood urea shortly rose from 130 mg. to 270 mg. within a few days, and the man died uræmic. During life the kidneys were not felt, but albumin and occasional red cells were found in the urine.

In demonstrating this patient I remarked upon the unusual softness and slow rise of the pulsation in the tumour, and recalled and summarized the case of hypernephroma previously seen and here described as Case 1. But because this patient had a clear X-ray picture of an enlarged aorta and a tracheal tug, a diagnosis of aneurysm pointing through the chest wall seemed unavoidable, the urinary symptoms being ascribed to renal sclerosis and insufficiency.

At autopsy the heart was found greatly enlarged, the pericardium completely obliterated by old adhesions. The aortic valves were very atheromatous and a little incompetent. The aorta was greatly dilated, and its wall presented gross syphilitic changes. But there was no aneurysmal projection through the sterno-clavicular joint, which was occupied by a deposit of new growth, spreading from the manubrium sterni and secondary to a large hypernephroma of the upper pole of the right kidney. The left kidney was granular on the surface and very fibrotic on section.

Summary

Two cases are briefly described in which pulsating tumours over the upper part of the sternum in syphilitic subjects seemed to indicate pointing aneurysm. Both tumours were in fact secondary deposits from hypernephroma, though in one case aneurysmal dilatation of the aorta was present as well. The cases are of interest in emphasizing softness and slowness and a slight but just distinct delay in the rise of the pulse in these pulsating neoplasms.

ŒSOPHAGEAL ELECTROCARDIOGRAMS IN AURICULAR FIBRILLATION*

BY

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A critical study of electrical events occurring in the posterior portions of the human heart has been made possible by the use of œsophageal leads in clinical electrocardiography (Cremer, 1906; Lieberson and Liberson, 1934; Luisada, 1935; Brown, 1936*a*, 1936*b*; Hamilton and Nyboer, 1938; Spühler, 1938; Nyboer, 1939; Deglaude and Laubry, 1939). The œsophagus lies close to the posterior surface of the left auricle, being separated from it by a space, 0·5–1 cm. wide, composed of areolar tissue and by the two layers of the pericadium The right auricle lies 4–6 cm. anteriorly, across the cavity of the left; but beneath the most inferior part of the left auricle the œsophagus is separated from the inferior vena cava and the right auricle by a distance of only 1–2 cm.

Brown (1936*a*) showed that an electrode lying in this part of the œsophagus provided a nearly direct lead for the surface of the left auricle and, when paired with a distant electrode, was capable of recording faithfully the electrical changes of this region. From his study of 21 patients exhibiting auricular fibrillation Brown (1936*b*) concluded that, when it has become established and is not liable to spontaneous reversion to normal rhythm, the auricular deflections recorded by the œsophageal lead are of small amplitude and irregular form and do not exhibit intrinsic deflections, although the electrode lies against or close to the posterior (left auricular) segment of the pathway round which a circulating mother impulse is supposed to travel. Deglaude and Laubry (1939) also failed to record intrinsic deflections. Brown, however, did obtain records showing intrinsic deflections from two patients in whom fibrillation was associated with thyrotoxicosis; in one of these normal rhythm appeared after thyroidectomy. He suggested that, when auricular intrinsic deflections are recordable by the œsophageal lead, fibrillation may not be firmly established and may be susceptible to spontaneous reversion.

We decided therefore to examine by means of the œsophageal lead cases of auricular fibrillation in which the arrhythmia was known to be paroxysmal or

* The results of this study were presented in abstract before the Edinburgh Pathological Club in March, 1939.

those in which normal rhythm was restored by quinidine, and to compare the resulting curves with those obtained from cases of established fibrillation.

The method employed, modified from that of Brown, has been described (Hamilton and Nyboer, 1938). Records were obtained in each case from several auricular levels as well as from supra- and infra-auricular sites. Repeat œsophageal cardiograms were always made from the same levels as the original records except where otherwise stated in the figures.*

Nine patients exhibiting auricular fibrillation were studied. Reversion to normal rhythm occurred in four, quinidine having been given to three of these, and in the other five fibrillation persisted.

I. Cases that Reverted to Normal Rhythm

In all four the auricular deflections recorded by the œsophageal lead were of greater amplitude than those in the standard lead tracings.

Three cases where auricular intrinsic deflections were recorded

Case 1 was that of a female, aged 35, suffering from chronic rheumatic mitral disease; she had had short attacks of dyspnœa for fifteen years, paroxysmal fibrillation having been recorded several times during the previous three years. Digitalis was given for the relief of congestive cardiac failure, but no quinidine.

Cardiograms (Fig. 1 B) by standard leads showed auricular fibrillation with coarse " f " waves having a maximum amplitude of 0·3 mv. In the œsophageal cardiograms † numerous auricular intrinsic deflections were seen, often in pairs or groups separated by smaller, irregular, slurred waves. A normal curve is shown for comparison in Fig. 1 A. The maximum amplitude of the auricular deflections was 0·6 mv. and the minimum less than 0·1 mv. After reversion to sinus rhythm normal œsophageal curves were obtained.

Case 2 was that of a male, aged 48 years, suffering from coronary arterial disease and chronic alcoholism. Fibrillation started two weeks before admission with sudden palpitation, dyspnœa, and œdema which was not relieved by full digitalization; salyrgan, however, caused marked diuresis and the patient lost 43 lb. of weight in seven days with clinical improvement. Fibrillation was still present five weeks later. Normal rhythm was restored when 1·0 g. of quinidine sulphate had been taken in two days, and remained for a further six months during which he took no quinidine.

Standard lead cardiograms (Fig. 1 C), made before quinidine was given, showed fibrillation with low voltage " f " waves having a maximum amplitude of 0·2 mv. Œsophageal cardiograms contained many auricular intrinsic deflect-

* Since the work recorded in this paper was carried out the joint recommendations of the American Heart Association and the Cardiac Society of Great Britain and Ireland relating to the method of recording præcordial and other semi-direct leads have been generally accepted. We have therefore reversed all œsophageal lead curves in this paper so that they conform in appearance to those which may be obtained by the new method of leading.

† In this and all subsequent descriptions the term " œsophageal cardiogram " is used to refer to the tracing obtained when the electrode lay at the level of the auricles. The ventricular œsophageal electrocardiogram is not considered in this paper.

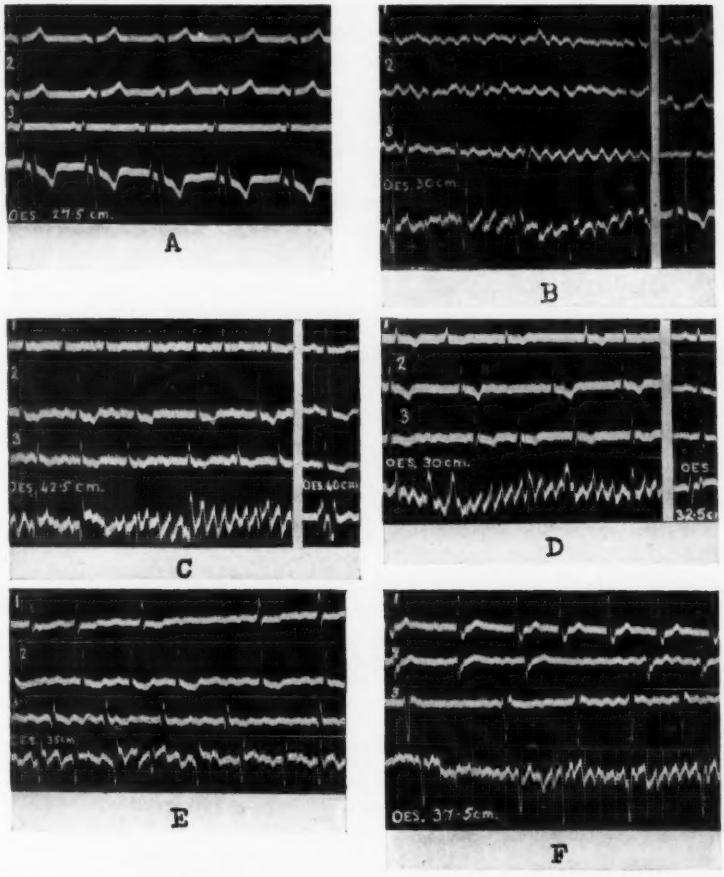

FIG. 1.—(A): Standard and œsophageal lead cardiograms of a normal male, aged 30 years, for comparison. In this and the other figures the distance of the mid-point of the œsophageal electrode from the incisor teeth is recorded. String sensitivity, 1 mv. = 10 mm. Time-marker, 0·2 and 0·04 second.

(B)–(E): Auricular intrinsic deflections in œsophageal cardiograms.
(B) Case 1; (C) Case 2; (D) Case 3: auricular fibrillation; subsequent normal rhythm.
(E) Case 5, (F) Case 6: auricular fibrillation; no return of normal rhythm.

ions; they occurred in groups separated by smaller, irregular, slurred waves, and had a maximum amplitude of 0·8 mv. and a minimum of less than 0·1 mv. After normal rhythm was restored they were of normal form.

Case 3 was that of a male, aged 53, suffering from arteriosclerosis and coronary arterial disease; he had complained of dyspnœa on exertion for one year. Rhythm was normal, apart from occasional supraventricular extrasystoles, until the tenth day after admission, when the auricles started to flutter at a rate of 300 per minute with a 2 : 1 A-V ratio. Fibrillation was induced by

digitalis and persisted for ten days, after which quinidine sulphate was given along with the digitalis; after 1·8 g. had been taken in two days normal rhythm reappeared and remained.

Fibrillation with small " f " waves, having a maximum amplitude of less than 0·1 mv., was shown in the standard lead cardiograms (Fig. 1 D) taken before quinidine was given. In the œsophageal cardiograms numerous auricular intrinsic deflections were seen, occurring in groups separated by smaller, irregular, slurred waves; they had a maximum amplitude of 0·7 mv. and a minimum of 0·2 mv.; after the reappearance of normal rhythm they were of normal form.

One case where no auricular intrinsic deflections were recorded

Case 4 was that of a male, aged 56, suffering from arteriosclerosis and coronary disease. Paroxysms of fibrillation had been recorded repeatedly during the preceding four years, and had usually ceased spontaneously though digitalis had often been given. The paroxysm observed by us lasted for two days and ended after 0·2 g. of quinidine sulphate; no digitalis had been given.

During the paroxysm standard lead cardiograms (Fig. 2 A, see page 267) showed fibrillation with small " f " waves having a maximum amplitude of 0·1 mv. In the œsophageal cardiograms the auricular deflections were very irregular in size and form, being only slightly larger than the " f " waves of the standard lead curves. Although many feet of record, obtained from various auricular levels, were studied, no certain instance of intrinsic deflection could be found. The auricular deflections had a maximum amplitude of 0·3 mv. and a minimum of 0·1 mv. Normal œsophageal curves were secured after normal rhythm reappeared.

II. Cases that did not Revert to Normal Rhythm

In all five the auricular deflections recorded by the œsophageal lead were of greater amplitude than those in the standard lead tracings.

Two cases where auricular intrinsic deflections were recorded

Case 5 was that of a female, aged 46, suffering from chronic rheumatic mitral disease and an acute exacerbation. She had had dyspnœa on exertion for six years. The presence of fibrillation had been recorded ten weeks before the observed hospital period during which the arrhythmia was continuously present. She received digitalis but no quinidine.

Standard lead cardiograms (Fig. 1 E, see page 265) showed fibrillation with " f " waves of moderate size having a maximum amplitude of 0·2 mv. In the œsophageal cardiograms the auricular complexes were of varying amplitude, some smaller and some larger than those in the standard lead curves. A few auricular intrinsic deflections were recorded, but these tended to occur singly and were separated by completely slurred waves; the maximum amplitude was 0·5 mv. and the minimum less than 0·1 mv.

Case 6 was that of a male, aged 79, suffering from arteriosclerosis and coronary disease. He had had increasing dyspnœa on exertion for one year

and œdema of the ankles for five weeks. There was no definite episode suggesting the onset of the auricular fibrillation, which remained throughout his 18 days in hospital. He received digitalis but no quinidine.

Standard lead cardiograms (Fig. 1 F) showed auricular fibrillation with small " f " waves having a maximum amplitude of 0·1 mv. In the œsophageal curves numerous auricular intrinsic deflections were seen, occurring in groups between which were smaller, irregular, slurred waves; they had a maximum amplitude of 0·45 mv. and a minimum of less than 0·1 mv.

Three cases where no auricular intrinsic deflections were recorded

Case 7 was that of a male, aged 76, suffering from arteriosclerosis and coronary disease, who had complained of dyspnœa on exertion and œdema of the ankles for two years. Throughout this period auricular fibrillation was known to be present. He was given digitalis but no quinidine.

Standard lead cardiograms (Fig. 2 B) showed fibrillation with small, often imperceptible " f " waves having a maximum amplitude of less than 0·1 mv. In the œsophageal tracings the auricular waves were also small, though larger than those in the standard lead curves, having a maximum amplitude of slightly over 0·1 mv. Although records were made from many auricular levels no auricular intrinsic deflections were seen.

Case 8 was that of a male, aged 69, suffering from coronary disease and hypertension, with congestive cardiac failure in varying degree for three years.

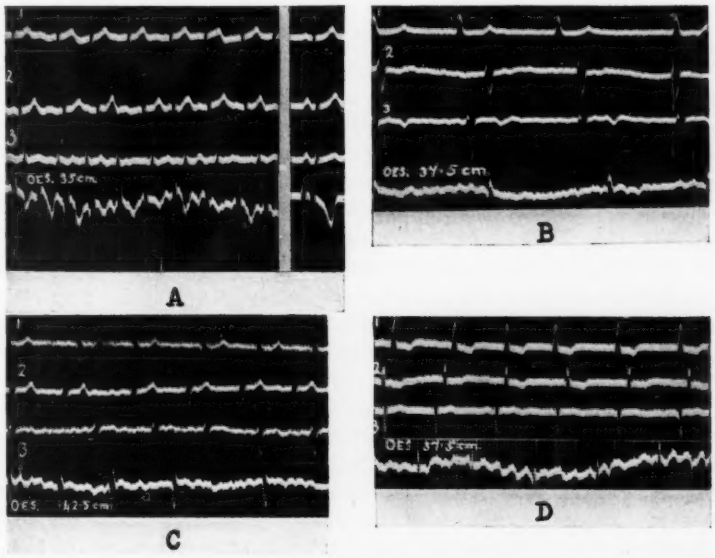

FIG. 2.—No auricular intrinsic deflections in the œsophageal cardiogram.
(A) Case 4: auricular fibrillation; subsequent normal rhythm.
(B) Case 7, (C) Case 8, (D) Case 9: auricular fibrillation; no return of normal rhythm.

Normal rhythm had been present two years before. Three weeks before admission he had a sudden increase in breathlessness and œdema, possibly indicating the onset of fibrillation, which was present on admission and remained. He was treated with digitalis, but was not given quinidine.

Standard lead cardiograms (Fig. 2 C), showed fibrillation with very small "f" waves having a maximum amplitude of less than 0·1 mv. Although œsophageal tracings were made from several auricular levels no auricular intrinsic deflections were seen; the auricular waves had a maximum amplitude of 0·2 mv. and a minimum of less than 0·1 mv.

Case 9 was that of a male, aged 60, suffering from hypertension. He was admitted with dyspnœa and œdema of the ankles of two weeks' duration. Auricular fibrillation was recorded several times during the first month when symptoms were severe, but normal rhythm appeared later as he improved under digitalis and salyrgan therapy. He remained well for three months after discharge, when dyspnœa and œdema suddenly returned; he was then readmitted. Although improvement again followed similar treatment, fibrillation was present throughout his three weeks in hospital. He received no quinidine.

Standard lead cardiograms (Fig. 2 D), taken during the second admission, showed fibrillation with very small "f" waves having a maximum amplitude of less than 0·1 mv. The auricular deflections in the œsophageal cardiograms, also taken at this time, were of moderate size having a maximum amplitude of 0·25 mv. and a minimum of less than 0·1 mv., but, although several auricular levels were examined, no auricular intrinsic deflections were recorded.

Discussion

Since we have recorded auricular intrinsic deflections by the œsophageal lead in five out of nine cases of auricular fibrillation, it would appear that such deflections are more frequently present in œsophageal cardiograms in this arrhythmia than has been supposed. The present work fails to support Brown's contention (1936*b*) that they are to be found only in cases liable to spontaneous reversion to normal rhythm. They were found in one case of paroxysmal fibrillation (Case 1), and in two of fibrillation of recent onset, responding to quinidine (Cases 2 and 3), but also in one case of fibrillation and rheumatic heart disease with a six years' history of congestive failure (Case 5), and in one case of fibrillation and coronary disease with a year's history of congestive failure (Case 6); in the last two auricular fibrillation might be expected to remain established.

On the other hand, auricular intrinsic deflections were not recorded in one case of paroxysmal fibrillation (Case 4), in one case in which normal rhythm had been present five months before (Case 9), in another in which normal rhythm had been recorded two years before and in which fibrillation may have been present for only three weeks prior to admission (Case 8), and in a fourth in which fibrillation was known to have been present for two years before admission (Case 7).

The presence or absence of auricular intrinsic deflections in the œsophageal lead tracings of cases of fibrillation does not indicate the likelihood or otherwise of reversion to normal rhythm, for, of the four instances of such reversion, one

(Case 4) showed no intrinsic deflections although the fibrillation was paroxysmal, and, of the five cases in whom the arrhythmia persisted, two (Cases 5 and 6) did show intrinsic deflections.

The work of Garrey (1914, 1924) and of Brams and Katz (1931) has produced evidence that, in experimental animals, induced auricular or ventricular fibrillation is not necessarily associated with the development of a circus movement of the impulse or of control of the activation of the muscle by a central circulating mother wave. Brown (1936*b*) analysed two simultaneous tracings taken by œsophageal leads in a case of auricular fibrillation and came to the conclusion that no central circulating wave was present in the auricles; no intrinsic deflections were seen in these records. It seems reasonable to suppose, from the records published by Brown and by Deglaude and Laubry, as well as from our own, that in many cases auricular intrinsic deflections are not obtainable. In these, therefore, there is no sign that co-ordinated activation of large muscle masses takes place, at any rate in the posterior part of the left auricle, such as would be expected if a central mother circus wave existed.

On the other hand, our records show that there are cases of fibrillation in which many auricular intrinsic deflections can be recorded. In these simultaneous activation of large muscle masses lying close to the electrode occurs frequently. The repetition of the deflections suggests the repetition of the same electrical process and is compatible with a central circulating impulse.

Brown's study (1936*b*) of œsophageal cardiograms in auricular flutter provides valuable evidence in support of the theory of Lewis and his associates (1921, 1925) that this arrhythmia is due to the continual circulation of an impulse round a more or less constant path. Brown's published and our unpublished œsophageal lead curves of flutter and the direct lead curves of experimental flutter published by Lewis (1921) show a close resemblance in the form of the auricular complexes to those obtained by us in auricular fibrillation (see especially Case 3, Fig. 1 D); this is striking enough to suggest that a similar mechanism is involved. However, two differences are apparent, namely, that in fibrillation the auricular rate is higher than in flutter (in our cases from about 375 to 500 per minute), and that in fibrillation the intrinsic deflections occur in groups separated by irregular smaller waves, whereas in flutter there is a constant wave-form. Sometimes, as in Case 5, intrinsic deflections are sparse, occurring singly. If the similarity between the auricular complexes in flutter and the complexes in fibrillation with intrinsic deflections can be considered to show that a circus movement exists in the latter, it must be argued that the path of the circus varies. When intrinsic deflections are recorded the circus must have passed close to the electrode but when the auricular complexes are small, irregular, and slurred, the path of the circus must have moved away from the proximity of the electrode, and the muscle near the electrode must have been irregularly activated in small masses by offshoots some distance from the central circus. A gradual change from complexes showing intrinsic deflections to slurred complexes without intrinsic deflections, suggestive of a gradual movement of the path of the circus away from the proximity of the electrode, is shown in Fig. 1 F (Case 6).

In the cases not showing intrinsic deflections long records were taken from various auricular levels. Since the œsophageal lead is capable of recording such deflections if long enough records are taken, it is probable that no mechanism involving the simultaneous activation of large muscle masses in the posterior wall of the left auricle or in the wall of the right auricle immediately medial to the entrance of the inferior vena cava was at work in these instances. In these cases the arrhythmia is unlikely to have been associated with a single circulating mother impulse.

Garrey (1924) stated that in experimental flutter and fibrillation there might be any degree of "circus movement" from a large-ring central mother circus in flutter to delirious fibrillation with many small ring-like circuits varying in location according to changes in the degree and position of local areas of block. The results of this study suggest that this hypothesis may be extended to human auricular fibrillation. At the one end of the scale are those in whose œsophageal cardiograms numerous intrinsic deflections occur, giving the tracings an appearance closely resembling those of auricular flutter. At the other end are those where the auricular deflections are small and irregular without any intrinsic waves.

Summary

1. Nine cases of auricular fibrillation have been examined by means of the œsophageal lead; in four a return to normal rhythm was observed.

2. Auricular intrinsic deflections were obtained in five cases, one of paroxysmal fibrillation, two of recent fibrillation responding to quinidine, and two in which the arrhythmia remained established.

3. Auricular intrinsic deflections were not found in the remaining four cases, one of paroxysmal and three of established fibrillation.

4. No association was found between the presence of auricular intrinsic deflections in the œsophageal cardiograms of the patients studied and the likelihood of reversion to normal rhythm.

5. The mechanism of auricular fibrillation is discussed in the light of the curves obtained.

We are greatly indebted to the physicians of the Boston City Hospital for permission to study these patients. The work was done while one of us (J. G. M. H.) held a Commonwealth Fund Fellowship at Harvard Medical School.

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MYOCARDIAL AND PERICARDIAL LESIONS DUE TO NON-PENETRATING INJURY

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Subacute and chronic affections of the myocardium due to non-penetrating injuries have in the past been regarded as extremely rare. Traumatic rupture of the cardiac valves, papillary muscles, and chordæ tendinæ are described in detail in most textbooks; yet isolated myocardial and pericardial lesions, though undoubtedly more common, are scarcely mentioned except in more recent manuals dealing with diseases due to trauma, such as those by Stern (1930), Brady and Kahn (1937), and Spicer (1939). Papers by Beck (1935) and by Bright and Beck (1935) have dealt especially with such cardiac muscle injuries.

In my monograph (Warburg, 1938) I analysed 189 collected cases of traumatic heart disease, 158 of which seemed well substantiated, and added 13 new cases. This covered the long period from 1676, when Oluff Borch observed the first case, to the end of 1937. To these 202 cases analysed in 1938, I can now add 54 published cases previously overlooked and 5 new unpublished cases, making 261 in all. After excluding some of the earlier ones as doubtful, there remain 225 well-substantiated cases to form the basis of this review. One third of these have been published during the last five years.

The 59 new cases, not included in my previous study, are as follows: Bricheteau (1844), Steiger (1864), Müller (1879), Barth and Roger (1880), Reynier (1880) two cases, Barber (1912), Fraenkel (1917), Krumbhaar and Crowell (1925), Coffen (1930), Meixner (1931) four cases, E. E. Davis (1931), N. S. Davis (1931) two cases, Jervell (1933), Gunewardene (1934), Hawkes (1935), Kampmann (1935), Schilder (1935), Bean (1937) three cases, Kissane (1937) nine cases, Barber (1938) ten cases, Kienle (1938), Moritz and Atkins (1938), Peters (1938) two cases, Störmer (1938), Campbell (1939), O'Farrell (1939), Smith and McKeown (1939), Rajasingham (1939), Wüllenweber (1939), and five unpublished cases observed by or communicated to me.

PERICARDITIS

Blunt injuries to the heart must often cause pericardial hæmorrhage or fibrinous exudation. In the previous material of 202 cases, involvement of the

* Dr. Warburg had agreed that his paper should be considerably reduced to make it suitable for publication in this Journal. We are greatly indebted to Evan Bedford for compressing so much of the substance into much shorter compass.

pericardium was mentioned in at least 50, and in the new material in 10 cases, but I believe that pericardial lesions are actually far more frequent than is indicated by these figures. The diagnosis usually rests on pericardial friction sounds, but sometimes characteristic splashing sounds have been heard (*bruit de moulin, bruit de rou hydraulique*), indicating pneumopericardium; four such cases were found in my first series and I have since discovered six more, summarized below.

(1) *Bricheteau* (*1844*).—A shoemaker, aged 59, was hit in the chest by a waggon shaft, after which he suffered from pain in the chest for some years. His wife could hear a gurgling sound in his chest. He was admitted to hospital with cardiac failure ; tympany over the præcordium and a *bruit de moulin* were observed. He died within a few days and post-mortem showed fibrinous deposit over the pericardium, which contained 250 c.c. of sero-purulent fluid and much air.

(2) *Steiger* (*1864*).—A rural worker, aged 35, fell down 26 steps and hurt the left side of his chest against the frozen ground, causing a fracture of the left radius and injury to the left shoulder. Severe pain and dyspnœa followed, and two hours after the accident a splashing sound or *bruit de moulin* was audible at a distance from the chest. In the horizontal posture the cardiac dulness had disappeared. His ribs may have been fractured, but there was no hæmoptysis and no evidence of pneumothorax. After some days the splashing sound disappeared and pericardial friction developed. The patient recovered completely.

(3) *Müller* (*1879*).—A stone-cutter, aged 28, was crushed between two large stone flags, fracturing both clavicles and the left fifth and sixth ribs. He became breathless, the pulse accelerated, subcutaneous emphysema of the left chest wall appeared, and pericardial and pleural friction sounds were heard. Soon the cardiac dulness disappeared and the *bruit de moulin* was audible, ceasing in three weeks' time, when pericardial friction reappeared. After a period of fever the patient recovered completely, and left hospital ten weeks after the accident.

(4) *Barth and Roger* (*1880*).—A man, who three months previously had a fainting fit, fell down 12 metres and fractured both his arms. Tympanitic percussion note was found over the heart and a definite *bruit de moulin* ; five months after the accident he had recovered.

(5) *Reynier* (*1880*).—A man fell down 5 metres and lost consciousness. He hurt his left side and felt severe pain in his left flank, where subcutaneous emphysema was found, reaching the præcordium. The fourth, fifth, and sixth left ribs were fractured. The *bruit de moulin* was heard with the patient lying, but disappeared when he sat up ; it lasted only 24 hours. No signs of pneumothorax. The patient seems to have recovered completely.

(6) *Reynier* (*1880*).—A man, aged 23, was crushed between the buffers of two railway carriages. He did not lose consciousness, there was no hæmoptysis, and shock was slight. He seemed to have fractured his fifth, sixth, and seventh left ribs. The *bruit de moulin* was heard and the cardiac dulness disappeared. One month afterwards he was discharged apparently cured.

Meixner (1931) has recorded a case of traumatic pericarditis with effusion in which 300 c.c. of clear fluid were aspirated, and Rajasingham (1939) another case in which 175 c.c. of hæmorrhagic pericardial fluid were removed ; both patients recovered. Paracentesis of the pericardium has, however, seldom been necessary, and in my previous paper there was only one case (Moullin, 1897) in which a large amount of fluid was removed by pericardiotomy. Characteristic cardiographic changes in a case of traumatic pericarditis have also been described (Smith and McKeown, 1939).

The prognosis in traumatic pericardial lesions that are not complicated by extensive myocardial damage or by infection is benign. I have only found four fatal cases in which myocardial lesions were not present post-mortem, and these were described so briefly that myocardial damage cannot quite be excluded. Three or four cases developed pyogenic pericarditis and in several the injury was followed by tuberculous pericarditis. Finally, intrapericardial adhesions have been observed and in one case a constriction syndrome developed (Warburg, 1933).

Auriculo-Ventricular Block

My previous paper included 6 published cases of A-V block; in 3 the block was transient (Howat, 1920; Rosenson, 1924; Touhy and Boman, 1931) and in 3 it was permanent (Laubry, Bloch, and Meyer, 1921; Gallavardin, 1922; Warburg, 1928). Four additional cases are summarized below.

(1) *Kampmann* (*1935*).—A chauffeur, aged 43, was cranking his car when it backfired and caused him to fall down. He felt a stinging sensation in his chest and shortly afterwards collapsed with severe chest pain. Vomiting and attacks of unconsciousness followed and he was admitted to hospital, where the heart rate was found to be 32–36. He recovered, but several Adams-Stokes attacks occurred later, the last one 22 months after the accident. A cardiogram taken over two years after the accident showed slight prolongation of the P–R interval.

(2) *Kissane* (*1937*).—A man, aged 35, passed as healthy at examination for life insurance nine months previously, was struck in the back by a slab of slating and doubled up. He felt a violent pain in his chest and was breathless. One month later the pulse was observed to be irregular, and he began to suffer from fainting fits. Six months after the accident examination showed enlargement of the heart and a systolic murmur. A cardiogram showed partial A-V block. He died nine months after the accident in a syncopal attack.

(3) *Coffen* (*1930*).—A healthy boy, aged 3, fell four feet, hitting his chest; no external injuries were noted. Next morning the heart rate was 65 and later in the day 50. The rate fell to 36 in the following few days. At the age of 10, complete heart block was recorded by cardiogram. There was a pulmonary systolic murmur and X-ray showed a prominence due to the left auricle.

(4) *Schilder* (*1935*).—A man, aged 66, giving a history of being kicked on the chest in childhood, had been subject to paroxysmal tachycardia for five years. Examination showed signs suggesting arteriosclerotic aortic stenosis and incompetence, hypertension, and cardiac enlargement. Aged 66, he was struck by a waggon shaft on the lower part of the sternum, following which he collapsed and remained unconscious for three-quarters of an hour. Bradycardia, rate 35, was noted within 15 minutes of the accident, and two days later 2 : 1 block was recorded. Frequent Adams-Stokes fits followed, in one of which he died, four months after the accident. Autopsy showed considerable hypertrophy of the heart and myocardial fibrosis. The coronary arteries were stenosed and calcified, but the valves were normal.

The prognosis in traumatic heart block is not always bad. Of the ten cases cited, four died while under observation; one lived 6 weeks, one 4 months, one 9 months, and one 13 years. The remaining cases were alive and under observation for periods of 1, 1 1/2, 4 1/2, and 5 years respectively; one, only observed for 3 months, was quite well. Heart block of undetermined ætiology is by no means rarely seen, especially in young subjects, and in some of these cases it may be due to trauma. In three of the cited cases with permanent

heart block due to trauma, the age at the time of injury was 3, 16, and 21 years respectively.

Sino-auricular Block.—Kissane (1937) has described a case of contusion of the heart in a soldier who was struck on the chest by a bayonet, near the apex beat. He became breathless and felt pain in the left chest and shoulder; a systolic murmur appeared at the apex. Eighteen years later a cardiogram showed sino-auricular block.

Changes in the Ventricular Complex of the Cardiogram

The best evidence that injury has caused a myocardial lesion is a changed ventricular complex appearing immediately after the trauma. Usually the changes observed have been regressive, but occasionally progressive changes have been recorded.

My previous paper included 12 cases of injury that caused cardiographic changes such as heart block, auricular fibrillation, and flutter, and also QRS and T changes. My new material includes 8 further cases as follows : Kissane (1937), curves of posterior infarction; Kienle (1938), T wave changes of posterior infarction and nodal rhythm; Störmer (1938), T wave changes of posterior infarction; Smith and McKeown (1939), R–T elevation followed by T inversion associated with pericarditis; Kissane (1937), R–T elevation in lead III followed by low voltage curves; Meixner (1931), T inversion and slurring of QRS, followed by auricular fibrillation; Campbell (1939), low voltage T_2 and inversion of T_3; lastly my own case, summarized below.

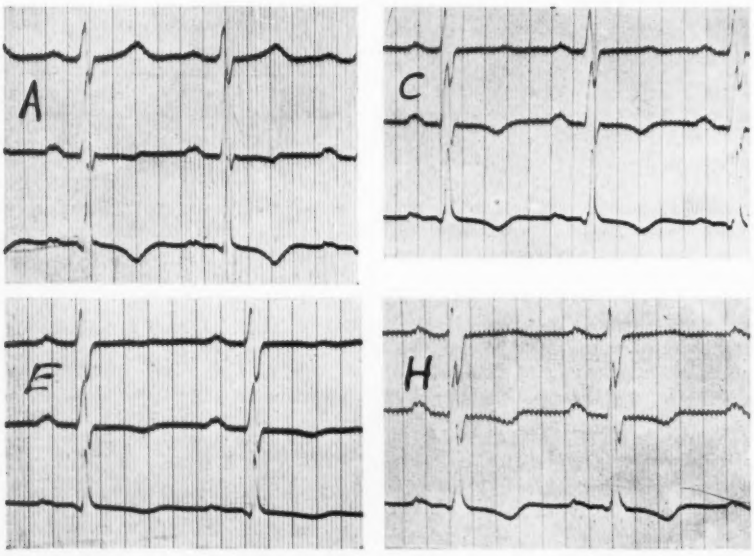

Fig. 1.—Serial cardiograms from case of myocardial trauma five months after the accident (A) April 13 ; (C) April 30 ; (E) May 16 ; (H) June 9, 1938 (leads I, II, and III from above downwards in each cardiogram).

Warburg (*1938*) (*case communicated by Dr. Voght-Moller*).—The patient had enjoyed good health up to November 1937, when he slipped and fell while loading turnips into a cart ; he felt pain in the chest radiating to the right arm, became breathless, sweated, and lay on the ground for five minutes. He was unable to work for some days, and after a temporary improvement became more breathless. Five months after the accident he was admitted to hospital suffering from violent attacks of pain in the chest combined with tachycardia, rate 160. Systolic and diastolic aortic murmurs were audible, with the Wassermann reaction negative. He died of cardiac failure eight months after the accident. During his stay in hospital, seven cardiograms were obtained, four shown in Fig. 1. The later curves show inversion of T in leads II and III and an isoelectric T in lead I.

Autopsy.—Heart weight, 270 g. No pericarditis. Right auricle distended ; left auricle normal. Valves normal. Ventricles normal. Just below the aortic valves a minute yellowish thickening of the endocardium of the left ventricle. Coronary arteries normal. Section of the heart showed a thin area on the lower posterior wall of the right auricle to which a few small thrombi were adherent, and the auricular appendix also contained thrombi. Sections of the ventricular and septal muscle showed no appreciable abnormality.

Thus at least 23 cases with transitory changes in the cardiogram following injury have been reported; 2 of these are known to have died after nine months and five years respectively. In 14 cases the period of observation varied from a few weeks up to seven years. In 8 cases recovery was stated to be complete. Thus the prognosis in the milder cases is good, especially if the patient is not too old and has not had previous cardiac symptoms.

Auricular Fibrillation

Auricular fibrillation is not rare in traumatic myocardial lesions, and my previous review included 41 cases of established and 4 of transitory fibrillation or flutter. The new material includes 10 cases of complete irregularity, i.e. one fifth of all cases, as in my previous series.

The new cases are summarized below.

(1) *Jervell* (*1933*).—An athlete, healthy when examined previously, was knocked down by a car, which struck the back of his chest. Shortly afterwards the pulse became rapid and irregular ; a cardiogram, nine months later, showed auricular fibrillation. Normal rhythm was restored by quinidine and the patient remained well during two years' observation.

(2) *Bramwell* (*1934*).—A mason, aged 35, previously healthy, struck his head against a beam ; he vomited and had severe headache for some days. Nine days after the accident auricular fibrillation was found, without cardiac enlargement or signs of failure. Neurological examination was negative. Normal rhythm was restored by quinidine and he was well a year later.

(3) *Barber* (*1938*).—A healthy man, aged 58, was hit on the head by a signboard and entered hospital with an injury of the cervical spine. His pulse, at first 80–90, accelerated to 120 after ten days, and a cardiogram three months later showed auricular flutter. Heart enlarged : B.P. 160/100 mm.

(4) *Barber* (*1938*).—A man, aged 61, was admitted to hospital after being run down by a car, and a few days later his pulse became irregular. His capacity for work diminished, and eleven months later a cardiogram showed fibrillation, apart from which the heart was normal. Five years later there was no change.

(5) *Barber* (*1938*).—A man, aged 63, was run down by a car, and on admission to

hospital a cardiac irregularity was noted. On leaving hospital he was breathless, and six weeks after the accident a cardiogram showed auricular fibrillation ; otherwise the heart was normal.

(6) *Kissane (1937).*—A man, aged 45, previously healthy, was hit on the back by a slab of slate and fell against a waggon, fracturing the second and third left ribs. Dyspnœa, pain in the chest, and hæmoptysis followed, and auricular fibrillation developed. Two years later there was cardiac enlargement and failure. A cardiogram showed fibrillation. Six years after the accident he was worse.

(7) *Kissane (1937).*—A man, aged 55, previously healthy, was struck on the sternum in a motor accident, and on admission to hospital the heart was irregular. He suffered from dyspnœa and sternal pain on effort, and, six months later, had a cerebral embolism. Nine months after the accident there was auricular fibrillation, cardiac enlargement, and signs of failure.

(8) *Moritz and Atkins (1938).*—A man, aged 74, was run down by a car, sustaining extensive injuries including fractures of two ribs. Auricular fibrillation developed the next day, and he died of heart failure ten days afterwards. Necropsy showed fibrinous pericarditis, hæmorrhages into the right auricle, extensive coronary sclerosis without recent thrombosis, and hæmorrhagic necrosis in an old infarcation of the right ventricle, regarded as of traumatic origin.

(9) *O'Farrell (1939).*—A man, aged 59, experienced severe pain in the left chest and dyspnœa, after a motor accident. There was fracture of a left lower rib. Three weeks later he had an attack of dyspnœa and auricular fibrillation was found. He died of heart failure three months after the accident. Necropsy showed a left pleural effusion, pericardial thickening, and adhesions at the apex, covering a cardiac aneurysm and myocardial fibrosis. Slight sclerosis of mitral and aortic valves. No coronary occlusion.

Thus of 10 cases of fibrillation, 2 recovered completely, 2 died ten days and three months after the accident respectively, and the remaining 6 showed signs of cardiac impairment.

Extrasystoles

Extrasystoles following trauma have seldom been reported. My original paper included 9 cases and there are only 2 additional ones. Barber's patient, a syphilitic, was injured by a bull, fracturing three ribs, after which the pulse was irregular from frequent extrasystoles, and remained so a year later. Meixner's patient, besides extrasystoles, had T wave abnormalities in the cardiogram.

Angina Pectoris

The possibility of angina pectoris being caused by trauma was first discussed by Hans Kohn (1929), who collected 4 cases; 2 of these seem doubtful and 2 had syphilitic aortitis, making it difficult to decide the role of trauma in the pathogenesis of the anginal syndrome. I was able to collect 13 published cases and to add 6 cases of my own, but only two thirds of these 19 cases could be accepted as well-substantiated.

Excluding cases in which the history was inadequate or in which the interpretation of the anginal symptoms was doubtful, my new material includes 16 cases of angina pectoris following trauma, as follows: Kampmann (1935),

Kissane (1937) 4 cases, Kienle (1938), Störmer (1938), Barber (1938) 4 cases, Peters (1938) 2 cases, Wüllenweber (1939), Dahle (1939), and Warburg (1938).

These cases were mostly men over 40 years of age, who had been in good health prior to accidents that often involved injury to the chest, and developed anginal pain shortly afterwards. The following two cases may be cited as examples.

(1) *Peters* (*1938*).—A man, aged 54, free from cardiac symptoms, was involved in a car accident, fracturing his right arm. He was in severe pain for two days, and a week later developed oppression in the left chest and arm. There were no abnormal signs in the heart and the blood pressure was normal. He died during a severe anginal attack a fortnight after the accident. Necropsy: coronary sclerosis without occlusion; mild fibrosis and fatty infiltration of the myocardium. An insurance company refused to accept the accident as the cause of death.

(2) *Warburg* (*1938*).—A man, aged 62, previously healthy except for glycosuria, had a cycle accident in 1935 which caused a swelling in one rib. In April 1937 he was run over by a car. He continued his work with difficulty for a week, after which he developed severe pain in the chest and stayed in bed for two days. On attempting to return to work he again had violent mid-sternal pain extending to both arms, and had to return to bed. After this he was unable to work until January 1938. In August 1938 he was subject to typical angina of effort, but was able to do light work. Examination showed the pulse regular, rate 48. Blood pressure, 180/80 mm. No signs of heart failure. X-ray and cardiogram showed no abnormality.

In most cases the pathogenesis of the anginal pain is probably explained by a vascular lesion ; but Peters suggested that peripheral stimulation from a broken arm caused coronary spasm, and Wüllenweber suggested interference with the coronary vasodilator fibres in a case with injury to the spinal cord.

My previous study included 2 cases of coronary thrombosis and 1 case of injury to a coronary branch following accidents, and I know of 6 other cases of traumatic coronary occlusion. The following may be cited as examples.

Fraenkel (*1917*).—A soldier, aged 20, was wounded by a shell explosion which caused an injury to his right arm and also concussion. He died six months later with cardiac failure. Necropsy showed an aneurysm of the left ventricle due to an aneurysmal dilatation of the left descending coronary artery, which was blocked by thrombi. The lesion was attributed to general concussion due to the shell injury.

Muller (*personal communication*).—A barrister, aged 59, free from cardiac symptoms, was run over by a bicycle, falling on to his thorax and abdomen. He sustained no external injuries and was able to get up immediately and walk to his office. He continued his work during the following days, though he did not feel well and experienced substernal oppression when walking upstairs or uphill. Nine days after the accident he had a severe nocturnal anginal attack and was admitted to hospital. The clinical picture became typical of cardiac infarction ; there was fever, leucocytosis, and typical R–T changes in the cardiogram. He died two weeks after the accident, with cardiac failure. Necropsy showed thrombotic occlusion of the left descending coronary artery with a large cardiac infarct and recent pericarditis. There was arteriosclerosis of the occluded branch and to a lesser degree of other branches.

Non-penetrating Cardiac Injuries in Children

Hawkes (1935) reported the following case of cardiac aneurysm. A boy, six years old, was hit by a truck. The diagnosis was compression of the chest and multiple abrasions of the body. He was discharged after one week as cured. He continued his usual life at home until three months after the accident, when he came home from school feeling sick. While eating his supper he fell off his chair, dead. At autopsy a ruptured traumatic aneurysm of the left ventricle with hæmopericardium was found. The aneurysm was globular, thin-walled, and on the posterior surface of the ventricle. It measured 4 cm. in diameter with a rupture at the summit, 0·5 cm. in diameter. No rheumatic or syphilitic lesion was found. There was no chest wall injury or fracture.

Gunewardene (1924) has described the case of a boy, aged 9, who was crushed against a wall without receiving any obvious injuries. Ten days later he died suddenly while playing at school. Necropsy showed hæmopericardium from rupture of the left ventricle. Similar cases described by Groom (1897) and by O'Neill (1914) were cited in my original paper.

Site and Type of Injury

In almost all cases in which the site of the injury has been stated, the thorax has been involved, usually by being struck from the front. In several cases the back was hurt, in one the right shoulder, in one the head, and two patients fell on their buttocks. Injuries distant from the heart may damage it, though very rarely. The accidents occurring in the present series of cases were similar in nature to those in the first series, and are tabulated below. Details were given in 57 of the 59 cases.

Fall	18 cases
Blow from plank, etc.	10 ,,
Run into or run over	9 ,,
Ran into something	6 ,,
Injured by steering-wheel	4 ,,
Hit by a waggon shaft	3 ,,
Fist blow	2 ,,
Injured by starting-handle of car	1 case
Jammed	1 ,,
Pushed by bull	1 ,,
Bayonet lesion	1 ,,
Shell injury	1 ,,

Diagnosis

The diagnosis of traumatic myocardial disease depends on a careful history. Often the heart is not perfectly normal prior to the accident, and both arteriosclerosis and hypertension may be predisposing factors. This was so in 10 cases of my first series and in 14 cases of the new series. Meixner (1931) in discussing this question concluded that the coronary arteries were frequently affected in sudden exertion or in sudden falls, and that if there should happen to be a lesion making them susceptible to rupture, a coronary thrombosis might occur owing to rupture of the intima; or, on the other hand, an aneurysm of the

ventricle might occur with subsequent rupture, or a pericarditis with subsequent rupture of the auricle. Difficulty may arise because, in some cases, the patient's condition immediately following the accident is not conspicuously bad. More often than not the patients do not faint, and in the present 59 cases fainting was specified in only 4, while in 24 absence of fainting was explicitly stated. There may be a latent period of a few days up to several months between the accident and the appearance of cardiac symptoms, as happened in 10 of the present cases. Almost every known abnormality of the electrocardiogram has been observed, yet in many cases there was no abnormality.

Prognosis

It is impossible to generalize about prognosis. The present material includes cases that recovered within a few weeks, many that developed chronic heart failure, and others that died fairly soon after the injury. Of my previous series, 74 patients are known to have died from their traumatic cardiac lesion and in the present series 16 out of 59 cases ended fatally. The period of survival is known in 14 of these cases and was 7 days, 10 days, 10 days, 2 weeks, 3 months, 3 months, 4 months, 9 months, and 2 years respectively.

Summary

Another 59 cases of myocardial or pericardial damage due to non-penetrating blunt injuries have been collected and are reviewed with data from a previous series of 202 similar cases.

The traumatic cardiac lesions described include pericarditis, heart block, myocardial damage, auricular fibrillation and other disturbances of rhythm, and angina pectoris. Auricular fibrillation occurred in a fifth and angina pectoris in a quarter of these 59 cases. Seven cases of traumatic coronary thrombosis are cited.

In almost all cases the injury involved the thorax, sometimes fracturing one or more ribs, but in a small proportion injuries distant from the heart were responsible for cardiac damage.

Arteriosclerosis and hypertension were sometimes present and may have rendered the heart more susceptible to injury from violence to the chest.

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THE VASCULAR RESPONSE IN CHRONIC RHEUMATOID ARTHRITIS

BY

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It has been suggested that a deficient blood supply might bring about abnormalities in the joints, just as it can in other tissues, and that vascular disturbances might be an ætiological factor in the causation of rheumatoid arthritis and osteo-arthritis. Savage and Taylor (1939) by means of oxygen and carbon dioxide measurements in the joints have shown that in certain cases of these diseases such a deficiency may exist. Goldhaft, Wright, and Pemberton (1933) successfully repeated the work of Wollenberg (1909) who showed that ligation of the patellar blood vessels in a dog produced symptoms of hypertrophic arthritis. The relationship between lack of blood supply and osteo-arthritis is illustrated by the following case seen by one of us. A man of 59 years of age suffered for five years from pains in the left knee and hip, the area round the latter being dead cold to the touch. The X-ray examination showed marked osteo-arthritis in the left hip, the presence of some unabsorbed material on this side, and distinct signs of arteriosclerosis in the left lower thigh. The patient stated that the only injections he had received were of gold into both buttocks two years ago. The non-absorption of this material, together with arteriosclerosis and coldness, on the affected side only, pointed to a deficient blood supply.

Many rheumatic subjects are very sensitive to cold weather and complain of cold hands and feet, and this has led to many investigations on skin capillaries. Deviations from the normal have been described, such as constriction (Lunedei and Coradini, 1930, and Bisset and Woodmansey, 1932); decrease in the number of capillaries above joints, where there were Heberden's nodes, and where the capillaries were also constricted (Kovacs, Wright, and Duryee, 1933): these authors saw tortuosity of the small skin vessels in 60 per cent of cases of osteo-arthritis in comparison with 35 per cent in respect of rheumatoid arthritis, but they attribute this to the higher age of the former; they conclude that many changes from normal do occur in the skin capillaries and skin temperature, but owing to the lack of consistency of the observations they can not be considered as responsible for the pathological changes. Kersley (1937) agrees with this view.

The problem therefore is whether, apart from obstructed blood flow to the

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joints, there is any functional vascular abnormality that leads to changes in the joints in cases of rheumatoid arthritis of unknown origin. Disturbance in the vascular constrictor tone is likely to be suspected, as it is met with in the so-called Raynaud syndrome and in acrocyanosis. In both these maladies the arteriolar constrictor tone is increased and in acrocyanosis there is also atonia of the subpapillary venous plexuses of the skin. Patients suffering from these vascular disorders are, like rheumatic subjects, very susceptible to cold. If in rheumatic diseases abnormal tone is present, one would expect a reaction to heat and cold similar to that in Raynaud's syndrome or in acrocyanosis. A suitable means to test such a vascular response is by the use of contrast baths.

The normal reaction of the blood vessels to this type of bath has been determined by Uprus, Gaylor, and Carmichael (1936). Our experiments are based on the fact observed by Gibbon and Landis (1932) that immersing one forearm in hot water produced vasodilatation in the other arm as well. More particularly Woodmansey, Collins, and Ernst (1938) have studied this reaction in rheumatic subjects. The times of immersion which these authors employed were too short for any sufficient vascular response.

METHOD

The usual method of finding if the capillaries are dilated or constricted is by measurements of the skin temperature. We used the nail bed of the index or third finger. According to Lewis and Pickering (1933) this shows the earliest response when the arm is exposed to hot or cold air, owing to the presence of numerous arterio-venous anastomoses at the finger tips (Grant and Bland, 1931). Gibbon and Landis (1932) have confirmed such response when the arm is heated with warm water.

Skin temperature measurements were carried out by us using the well known thermocouple-galvanometer method. The room was kept at as constant a temperature as possible during an experiment, but it varied somewhat from day to day from 18° to 21° C. The subject was seated comfortably in a chair so that the arms were able to relax. The two thermocouples were fixed one on each hand, usually at the nail bed of the index, but sometimes of the third finger. Measurements were carried out at intervals, until the temperature of the digits showed a constant figure, usually after 10–20 minutes, but exceptionally after 40 minutes. One arm was then immersed in a large bowl containing warm or cold water, as the case might be. The temperature of the warm water was kept constant by an immersion heater. The temperature of the cold water changed very little in the short time (8–12 minutes) during which the arm was immersed. The amount of water was sufficient to cover the arm from the middle of the hand up to the middle of the biceps. The finger to which the thermocouple was attached remained well above the surface of the water. Temperature readings were noted at intervals of half a minute to two minutes, from the digits of the immersed and non-immersed arms. When satisfactory readings had been taken of the response to heat or cold, as the case might be, the hot water was changed for cold or vice versa. This process was repeated several times. It was not found possible to measure the rectal temper-

ature during an experiment, and we had to be satisfied with mouth temperatures. This invariably rose by 0·4°–0·5° C. when the arm was immersed in hot water, and fell (0·2°–0·3° C.) when the arm was immersed in cold water, a point which has already been discussed by other writers.

Observations on the Reaction to Contrast Baths

These have been carried out on the following groups:—

(A) Normal subjects (10 cases)

(B) Non-arthritic subjects with Raynaud's syndrome in various stages (such as when cold- or warm-handed) (8 cases)

(C) Non-arthritic subjects with acrocyanosis (5 cases)

(D) Subjects with rheumatoid arthritis—

(*a*) with a normal blood sedimentation rate (21 cases) ;

(*b*) with a raised blood sedimentation rate (9 cases).

We have selected from each group cases that showed a typical reaction.

(*A*) *Normal subjects*

The main features of the response of a normal subject to contrast baths are shown in Fig. 1.

(*a*) In cold water there is an immediate rapid fall in the temperature of the fingers of both the immersed and non-immersed arms.

(*b*) In hot water this fall continues for a short period (5–8 minutes) and is followed by a rapid rise of both fingers.

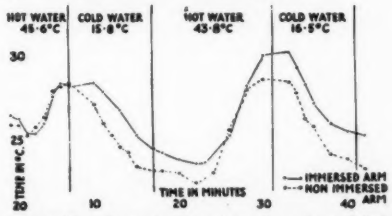

FIG. 1.—Normal subject, aged 38. In hot water there is a short fall in temperature, followed by a rapid rise in the digits of both the immersed and non-immersed arms. In cold water a rapid fall in temperature of both sides is shown. On immersion again in hot water there is a rapid rise in temperature after a delay of 6 minutes. After this cold water produces the usual rapid fall.

We found that if the initial skin temperature was high, that is if the arm was already in a state of vascular dilatation, then immersion in hot water could only produce a slight increase in this state.

(*B*) *Non-Arthritic subjects with Raynaud's Syndrome*

In general, patients suffering from this vascular disorder showed when they were warm-handed a normal or nearly normal response. When they were cold-handed the response was greatly delayed; but, once established, was normal in character. Variations occurred both from subject to subject and in the same subject at different times.

Observations on a typical case were as follows:

A woman, aged 33, had suffered for several years from cold arms, hands, and feet. Two years before sympathectomy had been performed on one leg without any effect on the Raynaud's syndrome. In particular the left hand and arm felt very cold, and the little finger showed marked cyanosis. Sometimes, however, the temperature of the hands was quite normal. There were no symptoms of arthritis or of heart failure.

We found variable reactions such as the following :

1. A complete lack of response to both heat and cold in both hands. The initial temperature of the digits was low (20·8° C. on the immersed, 20·3° C. on the non-immersed side). Cold water at 14° C. caused a drop in temperature on the immersed side to 17·9° C. in 10 minutes. On immersion in hot water at 45·5° C. no rise occurred even after 20 minutes' immersion. Subsequent immersion in hot or cold water could not release the vaso-constriction (see Fig. 2).

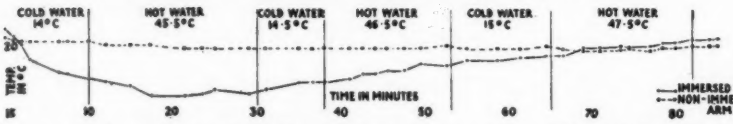

FIG. 2.—Subject suffering from Raynaud's syndrome. When cold-handed, practically no response in either side occurs, though at first the immersed hand becomes a little colder.

2. No response for a long time on the immersed side (initial temperature 20·4° C.) either in hot or cold, whilst the non-immersed arm (initial temperature 23·4° C.) had the paradoxical response of a rise in cold water at the beginning (see Fig. 3).

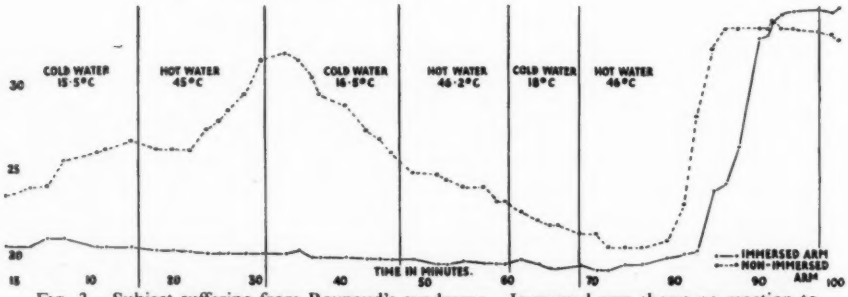

FIG. 3.—Subject suffering from Raynaud's syndrome. Immersed arm shows no reaction to heat or cold for a long time. A paradoxical rise in the temperature of the non-immersed arm to the stimulus of cold is shown; as also is the rapid response or both sides when this rise has gradually passed off.

3. When the same subject was investigated at a time that he was free from symptoms and warm-handed, an almost normal response was obtained on the immersed side, while the non-immersed side, after reacting poorly to cold, showed a normal response.

(*C*) *Non-Arthritic subjects with Acrocyanosis*

In general, subjects suffering from this disorder can show an almost normal reaction even when cold-handed; it is, however, characterized by the suddenness of the response to heat. On the other hand, after immersion in cold water, the vaso-constriction may become so intense that a response similar to Raynaud's syndrome when cold-handed is obtained. When response was established either to heat or cold, the graph representing the reaction did not proceed smoothly but showed an unexplained jerkiness.

The following case may be taken as typical: A woman, aged 27, had suffered from acrocyanosis in the hands, feet, and lower part of the legs for many years. There were no signs of disturbance in the endocrine glands nor of heart failure. Both hands felt cold to the touch and had a bluish-red colour. There were no signs of arthritis.

1. Sometimes there was a reaction that resembled the normal.
2. In another observation hot water produced a rise in temperature of both digits similar to a normal reaction, but more rapid. When immersed in cold water again there was a rapid fall in temperature which continued, when the arm was again immersed in hot water, for a long period, and no rise in temperature occurred (see Fig. 4).

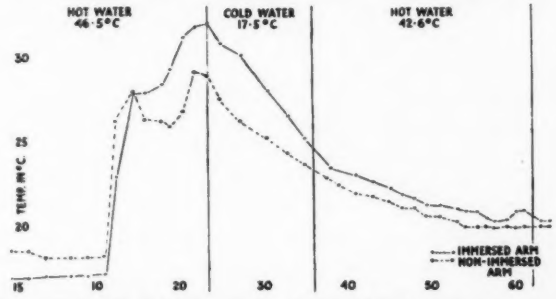

FIG. 4.—Subject suffering from acrocyanosis. The sudden rise in temperature of both sides follows the usual initial delay in hot water. Cold water produces an immediate fall in temperature, which continues on subsequent immersion in hot water, the latter failing to release the vaso-constriction even after 26 minutes' immersion.

(*D*) *Subjects suffering from Rheumatoid Arthritis*

(*a*) *With a normal blood sedimentation rate* (21 *cases*)

These subjects gave a typically normal response. Many observations were carried out at various times on each of these subjects in addition to many others, and all of them showed a normal reaction.

The following may be given as an example: A woman, aged 48, had hysterectomy performed 15 years ago, having previously had three normal births. B.P. was 170/110 mm. She had suffered from painful swelling in the right knee for three years. No marked bony changes were shown on X-ray examination. Blood sedimentation rate 5 (Westergreen method, 1 hour). The illustration has not been reproduced as it was similar to Figs. 1 and 5.

(*b*) *With a raised blood sedimentation rate* (*9 cases*)

The results obtained may be given under the following headings:

1. Rheumatoid arthritis, without any abnormalities of posture, showed a normal response to heat and cold.
2. Rheumatoid arthritis, characterized by a long history of infectious diseases and with marked anatomical changes in the joints associated with postural defects, gave a sluggish response at each observation.

The following cases may be given as examples :—

A woman, aged 58, had suffered from rheumatism after her first pregnancy. For some years she had pains in her finger joints and wrists with severe recurrent swelling and pain. On X-ray examination destructive changes in some meta-carpo-phalangeal joints. The blood sedimentation rate was between 14 and 19.

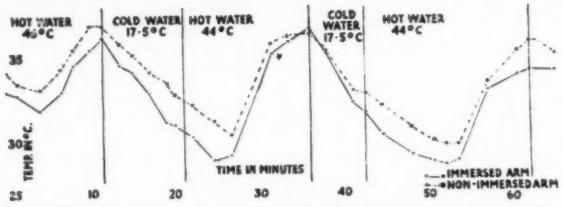

FIG. 5.—Subject with rheumatoid arthritis (raised blood sedimentation rate). A typically normal response.

A woman, aged 28, had suffered from many infections in childhood, but not from rheumatic fever. After scarlet fever rheumatic pains started with swelling in the hands, ankles, and elbows, and with iridocyclitis of the left eye. Her general condition was poor and she could not walk without orthopædic support because of severe deformities in both hands and feet. X-ray examination of the hands showed chronic rheumatoid arthritis with bony fusion of the carpal bones and ankylosis of several phalangeal joints. She had very pronounced deformities of the hands and arms. Her blood sedimentation rate was 40. There was a sluggish rise in temperature on the immersed side, while the non-immersed side showed a normal response (Fig. 6).

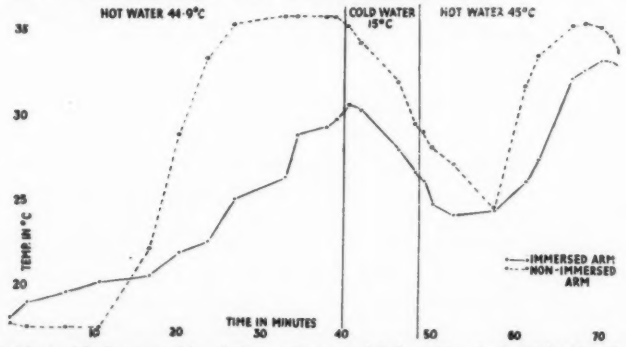

FIG. 6.—Subject with rheumatoid arthritis and postural deformities (raised blood sedimentation rate). A sluggish rise in temperature on the immersed side occurs while the non-immersed shows a normal response.

Discussion

The general features of the response of normal subjects to heat and cold closely resemble those obtained by Lewis and Pickering (1931–33), by Uprus, Gaylor, and Carmichael (1936), and by Gibbon and Landis (1932), although the actual limbs used and the procedure differed somewhat. Cooling one arm produces an immediate fall in temperature; heating one arm produces a delayed rise in temperature of both the immersed and non-immersed arm lasting from 8 to 10 minutes. Carmichael *et al.* (1936) pointed out that two factors are responsible for the cooling effect; the sensory stimulus producing vaso-constriction, and the cooling of the blood. The stimulus for the vascular dilatation is the rise in blood temperature; this must overcome the vaso-constrictor tone which may vary from subject to subject. When a normal subject was investigated, at one time with warm, and at another time with cold hands, the heat response under the latter conditions showed a delay which did not, however, exceed 8–10 minutes. Lewis and Pickering (1931–33) have shown that dilatation begins in the warmer fingers; the delay in response of the cooler fingers is attributed to the direct constrictor effect of cold on the arterioles. In cases of so-called Raynaud's syndrome with cold hands, when an increased vaso-constrictor tone is known to be present, not only is the time required to release the vaso-constriction lengthened, but the characteristics of such a response in the immersed and non-immersed limbs may be entirely different. In this vascular disorder we noted three principal types of reactions:

(*a*) the vaso-constrictor tone may remain unchanged in both arms;

(*b*) the vaso-constrictor tone may be released in one arm only, whilst the other side remains constricted;

(*c*) a paradoxical rise in cold and a fall in hot water may occur.

Once the reaction is initiated on both sides, it continues to be normal in type, as Lewis and Pickering have already pointed out. In acrocyanosis a rapid heat response may be obtained. However, after immersion of one limb in cold water the vaso-constrictor effect produced may be so great that subsequent immersion in hot water fails to release it.

In our subjects with rheumatoid arthritis of various types we have found no similarity, in their reaction to contrast baths, to these fundamental types of functional vascular disturbance. Rheumatoid arthritis and Raynaud's disease are only occasionally associated, whereas one would expect this more frequently if functional vascular disturbance were an ætiological factor in arthritis. One case of Raynaud's syndrome in which arthritic changes in the terminal joints of the finger were observed has been described by Lewis (1937); the changes were considered to be due to old re-canalized thrombi which severely restricted the blood flow to these joints—an anatomical cause for the condition.

The reaction of our arthritic subjects was tested on many different occasions in order to detect a possible temporary disturbance of vascular function; but even when the temperature of the hands was low, a quite normal response was obtained. Nor was there any sign of vaso-constriction that could not be released, such as occurs in acrocyanosis. The delay in heat response in these cases after immersion in cold water did not exceed the time observed in normal

subjects. A distinct delay in heat reaction was, however, noted in a severe case of rheumatoid arthritis of long standing, high sedimentation rate, and marked deformities of the arms and hands. Other subjects with all the same changes except the postural abnormalities gave a normal reaction. It has been found out by Uprus, Gaylor, Williams, and Carmichael (1935) that limbs with an abnormality in posture show a pronounced delay in heat response, which could also be elicited from a normal subject who imitated this abnormal posture. We are justified, therefore, in attributing the result in rheumatoid arthritis to this cause.

We conclude, that as far as the vascular system is concerned in the ætiology of rheumatoid arthritis and osteo-arthritis, a permanent arrest of blood flow caused by thrombi, by severe arteriosclerosis, or by any mechanical means, may produce joint and bony changes. In cases of vascular disorders like Raynaud's syndrome when associated with arthritis one has to consider the possibility of obstruction of the vessels leading to the affected area. No specific nor particular type of functional vascular reaction, as tested in contrast baths, could, however, be elicited in the various forms or stages of rheumatoid arthritis that we were able to investigate. This does not exclude the fact that many rheumatic patients are especially sensitive to cold, but this cannot be ascribed to abnormal vascular constrictor tone.

Summary

1. Arthritic changes have been seen in cases in which the blood supply to a joint has been restricted.

2. Investigations have been carried out to find if there might be any functional vascular disturbance in various types and stages of chronic rheumatoid arthritis. The reaction of rheumatic subjects to contrast baths has been compared with that of normal subjects and of subjects suffering from increased vasoconstrictor tone such as Raynaud's syndrome or acrocyanosis.

3. Unless a marked postural deformity was present all rheumatic subjects showed a reaction well within normal limits.

4. Several types of reaction to contrast baths were obtained in cases of so-called Raynaud's syndrome and acrocyanosis. There was no similarity to the reactions obtained in cases of rheumatoid arthritis.

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THE HEART RATE DURING A SIMPLE EXERCISE

BY

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Simple exercise tolerance tests, such as stepping on and off a stool a given number of times and noting the effect on the pulse rate, have long been used in medical practice. Almost invariably, however, the pulse rate is taken before and after, owing to the difficulty of counting it during the exercise. This may be overcome by means of a recording apparatus such as that of Bell and Knox (1938); the R–S waves of the electrocardiogram are recorded on a smoked drum, and the amplifier is modified to minimize the effects of skeletal muscle activity. Time in seconds, respiration, and signals for the beginning and end of exercise are also recorded on the drum, and thus a very complete and accurate analysis of the heart rate during even a short exercise is possible. Fig. 1 shows a normal trace obtained by this method.

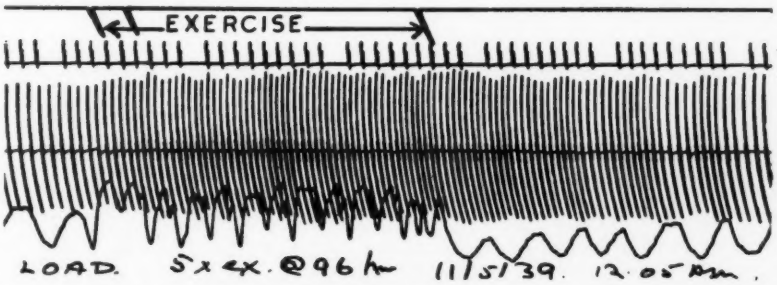

FIG. 1.—Portion of normal tracing showing the response to exercise. Upper tracing, signal showing the start and stop of the exercise. Second tracing, time in seconds, with a break once in 10 seconds. Third tracing, heart beats. Fourth tracing, respiration (the rise of the lever indicates expiration).

The exercise adopted as standard for this series is light enough to be suitable for many cardiac patients, and the movements required, viz. those of stair-climbing, enter into the routine of daily life. The advantage of this was pointed out by Master and Oppenheimer (1929) and by White (1937).

Seventy-five male medical students acted as subjects. They were in good health, but were not in training. Their ages, in nearly every case, lay between 18 and 22 years.

The Tolerance Test

As the test is designed with a view to clinical use, no extreme precautions are taken for obtaining a true basal initial rate, and slight latitude is allowed in the performance of the exercise. The subject first has a brief practice in ascending the steps, and after the chest electrodes and stethograph have been applied, he sits down on a chair eighteen inches high and relaxes as fully as possible.

The two chest electrodes employed are saucer-shaped copper discs 2·5 cm. in diameter. The concavity is filled with soft green soap which acts as the electrolyte, as recommended by Bell, Knox, and Small (1939). The electrodes are kept in contact with the chest by means of light elastic straps. One electrode is applied over the apex beat and the other over the second right costal cartilage. A satisfactory voltage and an even base line are obtained with the electrodes in these positions.

At the end of three minutes a tracing is run for 30 seconds, the subject remaining relaxed. The drum is then stopped and a further two minutes' rest allowed, giving five minutes in all; Master (1934) stated that this is usually sufficient to reach a steady resting rate. The drum is then started and the resting heart rate recorded for 15–20 seconds, after which the signal to start the exercise is given. The subject rises to his feet, steps five times up and down two steps each ten inches high and then sits down again and relaxes. To standardize the rate of climb the subject steps in time with a metronome beating 96 per minute. The average duration of the exercise from rising to sitting again is 24 seconds. It will thus be seen that the standard exercise of the present test is both lighter and of much shorter duration than that of the usual type of cardiac tolerance test.

Method of Analysing the Tracings

Fine vertical lines are drawn across the tracings at intervals of 5 seconds, starting 10 seconds before the beginning of the exercise. The heart rate is then counted (to the nearest tenth of a beat) in each of these intervals of 5 seconds, and the highest rate obtained is converted to beats per minute; this is taken as the maximum rate. The time to reach the maximum rate is taken from the beginning of exercise to the middle of the 5-seconds period with the maximum rate. For example, if the maximum rate is found in the third 5 seconds from the beginning of the exercise the time to reach the maximum rate is 12·5 seconds.

The heart rate in the 10 seconds immediately preceding the beginning of the exercise, converted to beats per minute, is taken as the initial rate.

The actual increase in beats per minute of the maximum rate over the initial rate is given, and this is also expressed as a percentage of the initial rate (percentage increase on initial rate).

The acceleration of the heart rate in beats-per-minute per second is calculated by subtracting the rate in the 5 seconds immediately preceding exercise (converted to beats per minute) from the maximum rate, and dividing the result by the time taken to reach the maximum rate.

Another index which may prove of interest is the number of extra heart

beats induced by the exercise. This is calculated by subtracting half the initial rate (in beats per minute) from the number of beats in the 30 seconds after starting the exercise, this including the whole of the exercise period.

To get an index that does not require the use of apparatus, the heart rate is counted over the 30 seconds beginning 5 seconds after exercise ends, this being called the post-exercise rate and expressed in beats per minute.

Example of the Analysis of a Typical Tracing

The heart beats in the successive 5 seconds, starting 10 seconds before the beginning of exercise, were as follows: 6·9, 7·0, 8·2, 10·0, 10·7, 10·5, 9·1, 8·6, 8·4. The duration of exercise was 25 seconds. The initial rate is therefore $(6{\cdot}9+7{\cdot}0)\times 6=83{\cdot}4$ beats per minute.

The maximum rate is $10{\cdot}7\times 12=128{\cdot}4$ beats per minute, and it occurs in the third 5 seconds from the beginning of exercise; therefore the time to reach the maximum rate is taken as 12·5 seconds.

The acceleration of the heart rate is $(128{\cdot}4-83{\cdot}4)\div 12{\cdot}5=3{\cdot}60$ beats-per-minute per second.

The number of beats in the 30 seconds after exercise began was 57. Thus the number of extra beats induced by the exercise was $57-1/2(83{\cdot}4)=15{\cdot}3$ beats.

The percentage increase on the initial rate was $(128{\cdot}4-83{\cdot}4)\times 100\div 83{\cdot}4=54$ per cent.

The actual increase in beats per minute was $128{\cdot}4-83{\cdot}4=45$ beats per minute.

The results are shown in Table I.

TABLE I

THE RISE OF PULSE RATE WITH THIS EXERCISE TOLERANCE TEST IN 75 HEALTHY MALE STUDENTS

Index	Mean	Range	Standard Deviation	Coefficient of Variation, Percentage
Initial rate, beats per minute	85·7	59–121	13·8	16·1
Maximum rate, beats per minute	130·2	109–168	12·9	9·9
Time to reach maximum rate (seconds)	15·0	7·5–22·5	—	—
Acceleration per second of heart rate in beats per minute	3·0	1·4–5·3	0·9	28·7
Extra beats	17·0	8·6–27·2	4·9	28·6
Percentage increase on initial rate	53·9	19·8–100	18·5	34·3
Actual increase in beats per minute	44·4	25–69	10·1	22·8
Rate after exercise, beats per minute	91·7	60–134	14·8	16·2

DISCUSSION OF RESULTS

(1) *Initial Rate.*—The mean rate of 85·7 beats per minute is somewhat higher than might be expected. The average sitting pulse rate in a corresponding age group was found to be 71–72 per minute by Volkmann (1850), and 70–72 per minute by McCurdy and Larson (1939), though Langowoy

(1900) gave an average of 80 per minute in a small series. The high initial rate of the present series is probably the result of psychological factors, as the subjects know that the exercise is about to start, though care is taken to see that the apparatus is not visible to them. This is borne out by the fact that the average heart rate taken after the first three minutes of rest is 81·5 per minute, while after a further two minutes of rest it has risen to 85·7 per minute just before exercise. Peabody and Sturgis (1922) found the same effect in normal subjects and in cardiac patients, and Addis (1922) showed the effect of excitement on the resting pulse rate. The accelerating action of mental factors on the heart was also pointed out by Gillespie (1924), Grollman (1929), and Ellis (1932).

Data on the variability of the sitting pulse rate appear to be very scanty, but Addis (1922) gave the average recumbent basal pulse rate as 80 per minute, and Jackson (1927) found an average recumbent rate of 80·2 per minute in 1600 male students, the coefficients of variation being 16 and 15·1 per cent respectively. Thus the coefficient of variation of the sitting pulse rate in the present series agrees well with these results quoted.

(2) *Maximum Rate.*—It is surprising that the mean maximum rate in a 5-seconds interval should be as high as 130 per minute in healthy young men performing a very light exercise. The maximum rate would appear to be a suitable index for measuring cardiac tolerance, as it is the least variable of the indices chosen, its coefficient of variation being only 9·9 per cent. If the initial heart rate is high the maximum rate reached is also high, the coefficient of correlation being +0·69 with a standard error of 0·116. This does not mean, however, that emotion simply raises the levels of the heart rates evenly throughout the experiment. In fact, where the initial rate is high the increase in the number of beats per minute produced by the exercise is generally low. For example, if the subjects are divided into those with initial rates below and above 85 per minute, the increase with exercise averages 48 beats per minute in the former, and 40 beats per minute in the latter.

This smaller increase is particularly noticeable in those whose resting rate just before exercise shows much increase over the resting rate two minutes earlier; these are presumably the subjects in whom the emotional element is greatest. It would thus appear that during the exercise the emotional increase is lessened and that some factor comes into play to prevent an excessively high maximum rate. Cotton, Rapport, and Lewis (1917) found a similar relationship between the initial and maximum rates recorded after the end of maximal exercise. They explained it on the assumption that " the circulation is capable at a given moment of a certain response to a given effort, and it appears to be a matter of indifference whether this response has been called forth to some extent before the chief stimulation has been applied, providing it has been called forth through similar channels." Boas and Goldschmidt (1932) made similar observations. In the present series, if emotion is considered to play the part of the introductory stimulus before the chief stimulus is applied, the results are in accordance with this theory, although the exercise is very far short of maximal.

(3) *Time of Occurrence of the Maximum Rate.*—It has been generally assumed that the maximum pulse rate reached during exercise occurs at the end. In exercise lasting one minute Peabody and Sturgis (1922) nearly always found the maximum rate during the last 15 seconds. Essex *et al.* (1939), working on dogs, found that in an exercise lasting about 15 minutes the maximum rate for a given amount of work was usually reached within one to three minutes of the beginning of the exercise, and that frequently the pulse rate fell well below the initial rise and remained fairly constant at the lower level. They pointed out that these findings in the dog are in striking contrast with those of previous workers, who found that in man the pulse rate continues to increase throughout the period of exercise until the maximal rate is reached.

The present findings closely resemble those of Essex *et al.* The maximum rate, instead of occurring at the end of the 24 seconds of exercise, is reached on the average 15 seconds after exercise begins. After this maximum the rate falls slightly and continues more or less level till the end. This, which is well shown in Fig. 2, does appear in the records of other workers, though it has

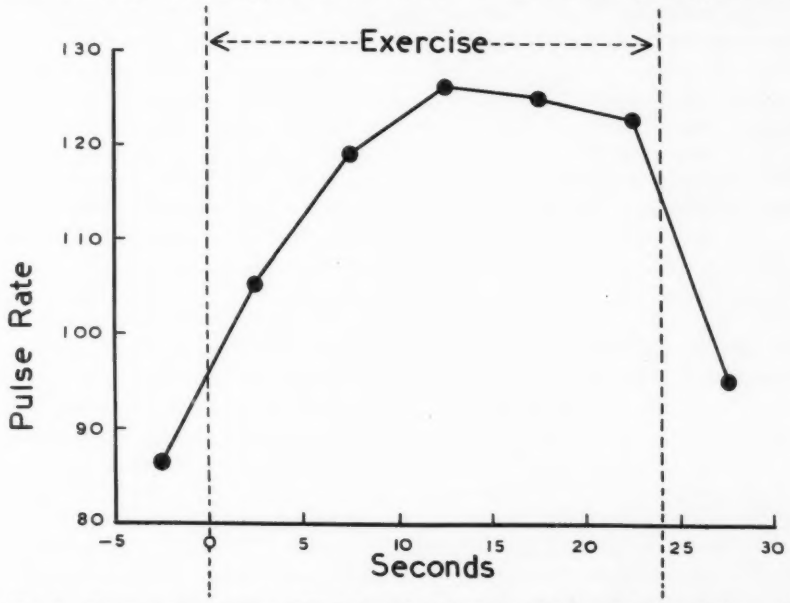

FIG. 2.—The average pulse rates of 75 male students in 5-seconds intervals before, during, and after the standard exercise. The average maximum rate here is slightly lower than that given in the table because the maximum rate does not always fall in the same 5-seconds interval.

not been stressed by them. In experiments on light work (tapping a key) by Bowen (1903) the average curve showed the maximum rate after two and a half minutes in an exercise lasting four minutes. Boas and Goldschmidt (1932) noted that in boys performing exhausting exercise for over three minutes the maximum rate was generally found two minutes after exercise began.

Paterson (1928) found in some cases an early maximum rate followed by a decline before a subsequent slower rise to the level of the early maximum. A curve given by Gillespie, Gibson, and Murray (1925) for light work also showed this effect, and Backwell (1921) (quoted by McDowall, 1939), obtained the same result when the start of the effort was sudden.

It was thought that our early maximum and subsequent slowing during exercise might be because the exercise was started from the sitting posture. Standing up might augment the rate during the first half of the exercise and this might pass off as circulatory adjustments are made. This, however, is not the case, as trials made with exercise starting from the standing posture still show the early maximum rate.

There are two main possibilities concerning the behaviour of the heart when an increased demand is made on the circulation.

The first theory postulates that the amplitude of the heart beat, i.e. its stroke volume or output per beat, is variable ; and thus the reserve capacity of the circulation lies mainly in variations of stroke volume and rate. The second theory postulates that the stroke volume remains nearly constant, and the demands on the circulation during activity are met mainly by variations in rate. A factor of safety is provided during exercise because the tissues are then able to take more oxygen out of a given volume of blood. This theory of the constant output per beat was supported by Henderson (1923 and 1925), while Henderson, Haggard, and Dolley (1927) found that the output per beat remained relatively constant during rest and moderate exertion in ordinary subjects, but that it might be much increased in athletes performing strenuous exercise.

The first theory, that of variable output per beat, was stated by Bainbridge (1919) and was supported by the experiments of Means and Newburgh (1915), and by later work of Lythgoe and Pereira (1925). On this basis, a theory to account for the early maximum rate and subsequent slowing of the heart during the exercise might be put forward as follows. Assuming the frequency and the output per beat to be independently variable, the increase in blood flow required by the exercise might be brought about in the early stages (the first fifteen seconds or so) mainly by increase in the rate, thus giving the rapid rise to the maximum rate. Then, in order to minimize strain on the heart muscle, the output per beat might increase enough to allow a slight slowing off in the rate, the exercise ending before any further increase in rate is needed. The observations of Means and Newburgh on the effects of increasing amounts of work tended to show that the output per beat increased before the frequency.

(4) *Acceleration of the Heart Rate.*—The chief point of interest of this index is that it is a measure of the acceleration of the heart rate, expressed as beats-per-minute per second, and not merely an expression of change of rate. It is, however, very variable, the coefficient of variation being as high as 28·7 per cent. As was pointed out long ago by Bowen (1903), Buchanan (1909), and others, the acceleration begins immediately the exercise starts, and this can clearly be seen on the tracings.

(5) *Number of Extra Beats induced by the Exercise.*—This index is of no great value in the present series of healthy men, but preliminary tests on patients

with heart lesions suggest it may be of interest. There was no significant correlation of extra beats and body weight in the present series.

(6) *Percentage Increase on Initial Rate.*—This has a high coefficient of variation and the variations occur over a wide range, no doubt because the maximum rate remains relatively constant while the initial rate varies widely. Hill, Magee, and Major (1937) found the percentage increase of pulse rate after two maximum pulls on a dynamometer to be very variable, but the absolute rise in rate was about the same in those with slow, medium, or fast resting rates.

(7) *Actual Increase in Beats per Minute caused by the Exercise.*—The relationship of this to the initial rate is dealt with under " maximum rate." The absolute increase in beats per minute here is very variable, in contrast with the results obtained by Hill, Magee, and Major (1937).

(8) *Heart Rate in the 30 Seconds beginning 5 Seconds after Exercise.*—This is highly correlated with the maximum rate, the coefficient being +0·83 with a standard error of 0·116. This index, then, which requires no apparatus and can be obtained by palpation, is a fairly reliable guide to the maximum rate reached during the exercise. The regression equation is : maximum rate=0·72 post-exercise rate + 64.

Cotton and Dill (1935) using a modified Boas' cardiotachometer recorded the heart rate in four periods of ten seconds each, two immediately preceding and two immediately following the end of exercise. The exercise consisted o walking and running on a flat treadmill and was continued long enough for a steady state to be reached. They concluded that the heart rate during exercise may be predicted from that recorded in the ten seconds following exercise, with an error whose standard deviation is less than 3 per cent ; and that the heart rate fell very little during the first ten seconds after the exercise, and for the next ten seconds only about 6 per cent. The conditions differed from those of the present series in that their exercise was prolonged until a steady state was reached; which, no doubt, accounts for the slow drop after the exercise, in contrast to the rapid drop observed in the present series (see Fig. 2). Gillespie, Gibson, and Murray (1925) stated that while the pulse rate just after exercise was a fairly reliable relative indication of the rate during the exercise, it was impossible to draw inferences therefrom as to the absolute rate.

Paterson (1928) found that the values of the pulse rate during exercise were much higher than one would expect from values taken even immediately after exercise. This is upheld by the present results.

Sinus Arrhythmia

Treadgold (1930) said that sinus arrhythmia was usually of no significance as regards cardiac efficiency unless it was extremely marked. As it is easily detected by the present method of recording, it may be of interest to give its frequency of occurrence. The tracings have been divided into four categories according to the degree of sinus arrhythmia. It was absent in 9 per cent; slight in 29 per cent; marked in 55 per cent; and very marked in 7 per cent.

Thus it will be seen that the condition was present to a marked degree in over 60 per cent of these normal young adults. Fig. 3 shows one such case. In

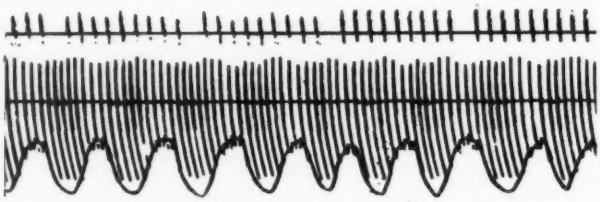

FIG. 3.—This tracing shows marked sinus arrhythmia. Upper tracing, time in seconds. Middle tracing, heart beats. Lower tracing, respiration (the rise of the lever indicates expiration, the fall indicates inspiration).

most cases the sinus arrhythmia disappeared during the exercise, but was especially prominent after it, perhaps due to deeper breathing. Dana (1919) described simple pauses in the heart beat, apparently dropped beats, which occurred in association with simple sinus arrhythmia. About 15 per cent of the present series show this condition in some degree (Fig. 4), but not always

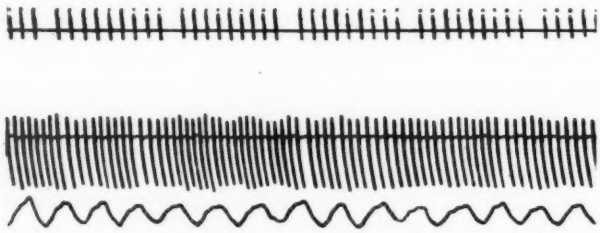

FIG. 4.—This tracing shows simple pauses in the rhythm of the heart. Upper tracing, time in seconds. Middle tracing, heart beats. Lower tracing, respiration.

those with marked sinus arrhythmia. The condition would appear to be some form of sinus block.

It is hoped that this somewhat exhaustive survey of results in a simple cardiac tolerance test will serve as a basis for further tests which are being carried out on the heart rate during exercise in patients with various cardiac esions.

SUMMARY

A simple two-step cardiac tolerance test of very brief duration is described, in which the subject's heart beats are electrically recorded on a smoked drum throughout the test.

From the analysis of the records of 75 healthy male students, the following indices are obtained and discussed: initial rate; maximum rate; time to reach the maximum rate; acceleration of the heart rate; number of extra beats induced by the exercise; actual and percentage increase on initial rate; and the rate after exercise.

The mean values and variability of these indices are given.

I wish to acknowledge my indebtedness to Professor E. P. Cathcart for his interest and encouragement during the progress of the work.

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WILLIAM WITHERING (1741–1799) AND EDGBASTON HALL

BY

K. D. WILKINSON

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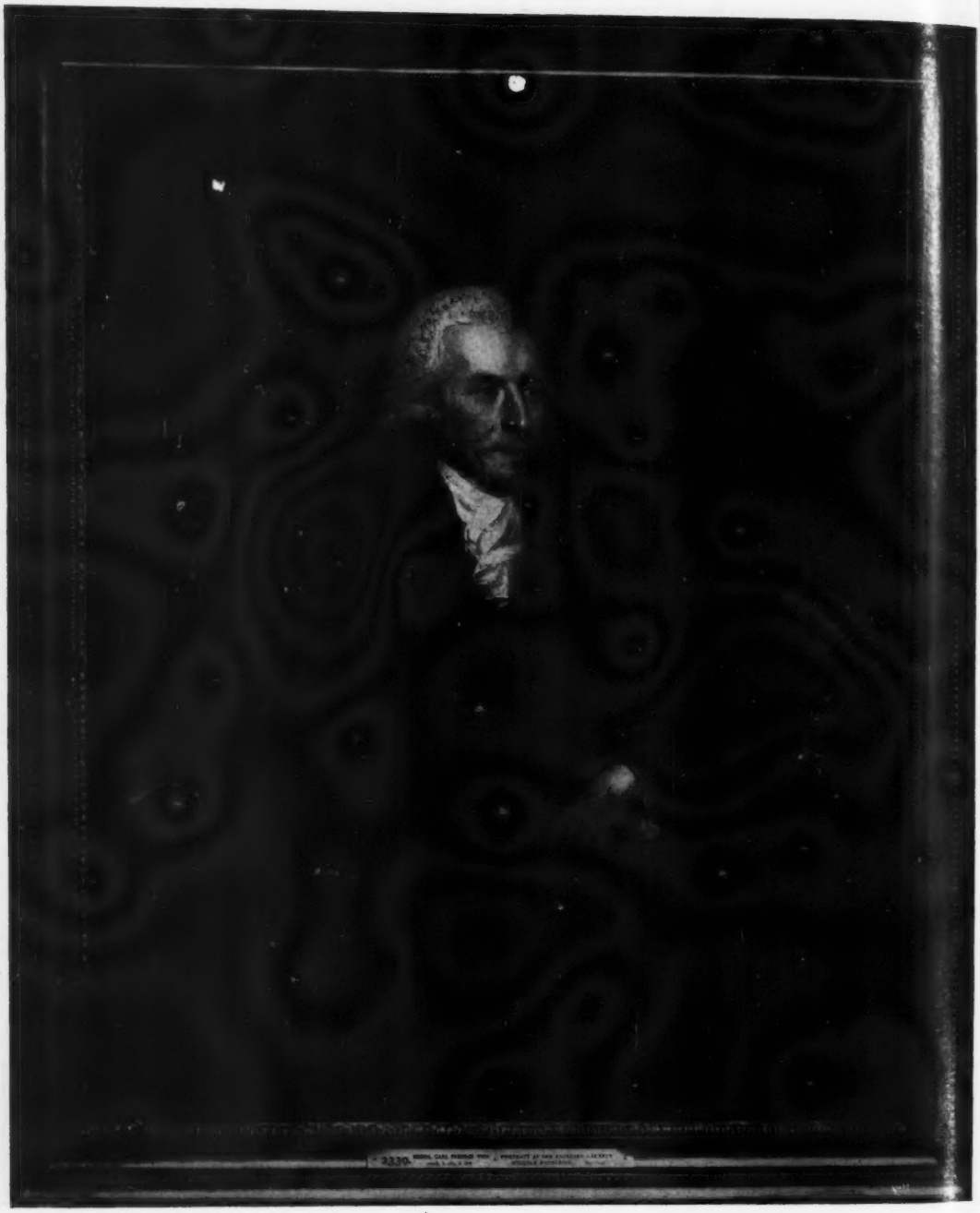
Edgbaston Hall, once the home of William Withering, and now the club house of the Edgbaston Golf Club, was the venue of the annual dinner of the Cardiac Society of Great Britain and Ireland for the Birmingham meeting in May 1939.

The estate is a very old one, and the present house has some close medical associations. The Manor of Edgbaston dates back to the Norman Conquest, when it was valued at thirty shillings a year; and in the reign of King Richard the second, through the marriage of Isabella de Egebaston to Thomas Middlemore, the estate passed to the Middlemores, with whom it remained for more than three hundred years. The Middlemores were an important Roman Catholic family in the Midlands, with very large estates of which the present Duke of Norfolk is co-heir. In 1635, as Roman Catholics, they forfeited their Edgbaston estates, but managed to obtain a forty years lease from the Crown on the payment of one hundred pounds a year. The size of Edgbaston Hall at this time may be judged from the fact that it paid hearth tax on twenty-two hearths.

During the Civil War, the Hall was held for Parliament by the notorious Colonel Fox, who maintained a garrison there for three years. He did so much damage that it was not again inhabited. In 1680, the Hall was dismantled, with the excuse of preventing it acting any longer as a refuge for Papists, and in 1717 the estate was sold to Sir Richard Gough, and shortly afterwards the Hall as it now stands was constructed. An illustration is shown on the next page.

William Withering obtained a fourteen years lease of the Hall and park in January 1786, at an annual rental of two hundred and thirty-seven pounds ten shillings. The lease also states that " he is to replace any sweet carp or tench removed from the pool, is not to dig, plough, break up, or convert into tillage, any part of the estate, under penalty; nor to plant flax seed, rape seed, wood madder, or potatoes, but he is to maintain the wheat crop."

In 1791, Birmingham had most serious riots, fomented by rival religious parties, but based upon political unrest and feelings against Dr. J. Priestley and others who approved the French Revolution. Edgbaston Hall was attacked, but escaped serious damage, being more fortunate than many of the mansions round the city. Withering was neither a non-conformist nor a



sympathizer with the Revolution, but any house that appeared worth looting was subject to attack, and he was known as a friend of Priestley.

It was at Edgbaston Hall that Withering maintained a botanical garden, and bred cattle and dogs—the cattle breeding was so successful that it paid his rents—and there he met and entertained many of the leading scientists and botanists of his time, for he had a European reputation not only as a physician, but also as a botanist and as a chemist. Shortly before he died in 1799, Withering left the Hall for a milder climate in Sparkbrook, but he only lived at "The Larches" for a week, for he moved on September 28, 1799, and died about 7 p.m. on October 6, aged fifty-eight years and six months.

He was buried in Edgbaston Church on October 10 and there still stands the mural monument with the representations of digitalis and the Witheringia.

In the inscription, he is said to have been born on March 28, 1741, but his son in the memoirs says that he was born on March 17, 1741; probably March 28 was the baptismal date.

To-day in the garden and grounds of the Hall there are still blooms of foxglove—descendants of those plants that Withering himself cultivated—and that surely is the best memorial to his memory.

EXTRACT FROM THE MINUTES OF THE THIRD ANNUAL GENERAL MEETING OF THE CARDIAC SOCIETY, HELD AT BIRMINGHAM ON THURSDAY, MAY 25, 1939. CHAIRMAN: K. D. WILKINSON.

Dinner was held at the Edgbaston Golf Club (Withering's old house), and the Society admired the fine portrait of Withering, lent by the Chairman to look down on the Society from the walls of his old dwelling-house. The original painting, of which this was an excellent copy, was by Carl von Breda and was bought for the Stockholm gallery where it hangs with this inscription:—

2339 BREDA, CARL FREDRIK VON,
svensk, f.1759, d.1818.
PORTRÄTT AU DEN ENGELSKE LAKAREN
WILLIAM WITHERING. sign. 1792.

[A photograph of this is shown on the previous page.]

John Hay, in his usual felicitous manner, proposed the health of the Society, coupled with the name of the Chairman. The Chairman (Wilkinson) replied with a charming sketch of some aspects of Withering's life and work, and proposed the health of the Secretary. The Secretary replied shortly.

John Parkinson

9th May, 1940

ERRATA

Page 101, line 15 : *for* 0·5 mV. *read* 0·05 mV.

Page 105, Summary, line 2 : *for* 0·5 mV. *read* 0·05 mV.

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